The Journal of Bone and Joint Surgery

UNIVERSITY
OF MICHIGAN
MAY 9 1951
MEDICAL
LIBRARY

The Official Publication of

The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association

APRIL 1951

American Volume

Vol. 33-A, No. 2

8 THE FENWAY, BOSTON 15, MASSACHUSETTS, U. S. A.
BRITISH OFFICE:
82 PORTLAND PLACE, LONDON, W. 1, ENGLAND

The Journal of Bone and Joint Surgery

PUBLISHED IN TWO VOLUMES

The Journal of Bone and Joint Surgery

AMERICAN VOLUME

Editor, and *Chairman* of the Board of Editors:
WILLIAM A. ROGERS
Treasurer, and *Chairman* of Editorial Committee:
FRANK D. DICKSON, Kansas City, Missouri

American Board of Associate Editors:
JOSEPH S. BARR, *Vice Chairman*
RUFUS H. ALLDREDGE, New Orleans, Louisiana
HARRY C. BLAIR, Portland, Oregon
WALTER P. BLOUNT, Milwaukee, Wisconsin
FREMONT A. CHANDLER, Chicago, Illinois
MATHER CLEVELAND, New York, N. Y.
JOSEPH A. FREIBERG, Cincinnati, Ohio
G. E. HAGGART, Boston, Massachusetts
VERNE T. INMAN, San Francisco, California
J. VERNON LUCK, Los Angeles, California
H. RELTON MCCARROLL, St. Louis, Missouri
MICHAEL L. MASON, Chicago, Illinois
LEO MAYER, New York, N. Y.
FRANK R. OBER, Boston, Massachusetts
WINTHROP M. PHELPS, Baltimore, Maryland
R. B. RANEY, Durham, North Carolina
A. R. SHANDS, JR., Wilmington, Delaware

The Journal of Bone and Joint Surgery

BRITISH VOLUME

SIR REGINALD WATSON-JONES, *Editor*

British Editorial Board

PROFESSOR GEORGE PERKINS, *Chairman*
PHILIP WILES, *Treasurer*
H. JACKSON BURROWS, *Deputy Editor*
J. CRAWFORD ADAMS, *Assistant Editor*
ROLAND BARNES, Glasgow, Scotland
J. M. EDELSTEIN, Johannesburg, South Africa
ALEXANDER GILLIES, Wellington, New Zealand
D. LL. GRIFFITHS, Manchester, England
R. I. HARRIS, Toronto, Canada
T. KING, Melbourne, Australia
W. L. MACDONALD, Sydney, Australia
B. L. MCFARLAND, Liverpool, England
E. A. NICOLL, Mansfield, England
H. OSMOND-CLARKE, London, England
G. PULVERTAFT, Derby, England
J. EDOUARD SAMSON, Montreal, Canada
J. C. SCOTT, Oxford, England
H. L. C. WOOD, London, England

WILLIAM A. ROGERS, *Editor-in-Chief*

Corresponding Editors

Argentina: JOSÉ VALLS
Austria: WALTER EHALT
Belgium: JEAN VERBRUGGE
Brazil: F. E. GODOY MOREIRA
Cuba: ALBERTO INCLAN
Denmark: JOHANNES MORTENS
Finland: K. E. KALLIO
France: MERLE D'AUBIGNE
Mexico: JUAN FARILL
Netherlands: J. D. MULDER
Poland: ADAM GRUCA
Portugal: ARNALDO RODO
Sweden: STEN FRIBERG
Uruguay: JOSÉ LUIS BADO

Editorial Committees

The American Orthopaedic Association
Treasurer: FRANK D. DICKSON, *Chairman*
President-Elect: FREMONT A. CHANDLER
Secretary: C. LESLIE MITCHELL
Henry Ford Hospital, Detroit 2, Michigan

The American Academy of Orthopaedic Surgeons
Past-President: GUY A. CALDWELL, *Chairman*
Treasurer: H. RELTON MCCARROLL
Secretary: HAROLD B. BOYD
869 Madison Avenue, Memphis 3, Tennessee

American Society for Surgery of the Hand
President: MICHAEL L. MASON
President-Elect: WILLIAM FRACKELTON
Secretary-Treasurer: JOSEPH H. BOYES
1401 South Hope Street, Los Angeles 15, California

The Australian Orthopaedic Association
G. A. C. DOUGLAS, Brisbane, Queensland
J. R. S. LAHZ, Brisbane, Queensland
T. KING, Melbourne, Victoria
B. T. KEON-COHEN, Melbourne, Victoria
E. F. WEST, Adelaide, South Australia
A. JUETT, Perth, West Australia
H. C. BARRY, Sydney, New South Wales
D. PARKER, Hobart, Tasmania
A. R. HAMILTON, *Secretary*, 138 Macquarie Street, Sydney, New South Wales

The British Orthopaedic Association
S. L. HIGGS, *President*
J. CRAWFORD ADAMS, *Editorial Secretary*
PHILIP NEWMAN, *Secretary*
45 Lincoln's Inn Fields, London, W.C. 2.

The Canadian Orthopaedic Association
J. E. SAMSON, Montreal
R. I. HARRIS, Toronto
ALEXANDER GIBSON, Winnipeg
WILLIAM B. MACKINNON, *Secretary*
661 Broadway, Winnipeg, Manitoba

New Zealand Orthopaedic Association
ALEXANDER GILLIES, Wellington, *President*
J. KENNEDY ELLIOTT, Wellington, *Secretary*
J. LESLIE WILL, Christchurch
H. WALDEN FITZGERALD, Dunedin
SELWYN MORRIS, Auckland, *Editorial Secretary*
3 Alfred Street, Auckland C. 1, New Zealand

Orthopaedic Surgeons' Group of South Africa
J. M. EDELSTEIN, Johannesburg
G. T. DU TOIT, Johannesburg
J. G. DU TOIT, Pretoria
ARTHUR HELFET, *Secretary*
National Mutual Building, Church Square, Capetown, South Africa

Owned and Published by
The American Orthopaedic Association

Published in the United Kingdom by
E. & S. Livingstone, Teviot Place, Edinburgh

THE JOURNAL OF BONE AND JOINT SURGERY

American Office
8 The Fenway, Boston 15, Massachusetts, U.S.A.
***Assistant Editor:* Florence L. Daland**

British Office
82 Portland Place, London, W. 1, England
P. G. Studholme, *Sub-Editor*

VOL. 33-A, NO. 2 APRIL 1951

The Journal of
Bone and Joint Surgery

American Volume

ORTHOPAEDIC SURGERY TODAY AND TOMORROW *

BY GUY A. CALDWELL, M.D., NEW ORLEANS, LOUISIANA

I should like to interrupt the scientific program of the Eighteenth Annual Meeting to invite you to consider with me the present status and future prospects of orthopaedic surgery. What I shall say stems from thirty years of practice in our specialty, together with seventeen years of service in an official capacity with one or another of our orthopaedic organizations. Since my medical undergraduate days, our specialty has emerged from its "strap-and-buckle" period, when it was represented by only a small group of orthopaedists, to its present status as an important surgical specialty. Since its first meeting in 1933, our Academy has come to be the world's largest orthopaedic gathering, presenting splendid programs and exercising far-reaching influence. The year following the birth of the Academy saw the establishment of The American Board of Orthopaedic Surgery, which has done much to raise the standards of training and qualifications for the practice of orthopaedic surgery.

The transition from an ill-defined group of orthopaedists in the nineteenth century to the well-established specialists in orthopaedic surgery of the twentieth century began with the efforts of Sir Robert Jones in England. Our specialty became recognized as a branch of surgery principally as a result of World War I. Here in America, the scope of our specialty was definitely established when The American Board of Orthopaedic Surgery adopted the definition that "Orthopaedic Surgery is that branch of surgery especially concerned with the preservation and restoration of the functions of the skeletal system, its articulations and associated structures". By this definition, we staked a claim to a large field in the practice of medicine. This claim has been accepted in effect by such national organizations as the American Medical Association and the American College of Surgeons, and the general public is gradually beginning to recognize the types of disorders which we orthopaedists should treat.

However, much remains to be accomplished before our claim is fully established, and always there will be overlapping, disputed areas at the periphery, when we may touch on the fields of general surgery, neurosurgery, plastic surgery, pediatrics, and the newly established specialty of physical medicine. Moreover, we must bear in mind that we have as direct competitors certain cultists and irregular practitioners,—such as osteopaths, chiropractors, chiropodists, and podiatrists. Thus, our position in relation to the claim we have staked indicates a need for liaison work. It appears that organized orthopaedic surgery needs to clarify its position, not only in the minds of the rest of the medical profession, but also in the minds of the people who are, will be, or should be, our patients. Before thinking of ways and means to accomplish these ends, we must be sure that we thoroughly understand ourselves. As physicians and as claimants to a special field, how do we rate?

During the past fifteen years we have raised the qualifications for practice of our specialty, and we now have high ethical and educational requirements for membership

* Presidential Address presented at the Eighteenth Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 31, 1951.

in our Academy and other orthopaedic societies. The oncoming generation of orthopaedic surgeons, upon which the future of our specialty depends, are being trained in hospitals that have been approved by the proper accrediting agencies of the American Medical Association, the American College of Surgeons, and The American Board of Orthopaedic Surgery. Whereas collectively and on paper our standards of training have been raised, the survey of our Joint Committee on Graduate Training five years ago indicated, nevertheless, that there were a number of institutions with inadequate training programs. There appear to be three principal reasons for this.

The first of these may be termed exploitation of the trainee, a sociological problem which has been largely overcome in other fields in our country today. Unfortunately, in certain hospitals, the training program is virtually a subterfuge, whereby the trainee spends three years giving valuable assistance in the care of orthopaedic patients, but receives little organized instruction and supervision in return. This amounts to exploitation of the trainee as a cheap laborer in the field of orthopaedic surgery. Blame for such exploitation rests squarely upon the orthopaedic staff members of these hospitals. Engrossed in their busy practices, they have lost sight of their teaching obligations and have forgotten that part of the Hippocratic oath in which each promised "to teach them this art, if they shall wish to learn it, without fee or stipulation; and . . . by precept, lecture, and every other mode of instruction . . . [to] impart a knowledge of the art to [his] own sons, and to those of [his] teachers, and to disciples bound by a stipulation and oath according to the law of medicine, but to none others". Therefore, each of us who is in any way connected with the training of interns, fellows, or residents should candidly examine his conscience to be sure that he is honestly fulfilling his teaching obligations to the best of his ability.

A second reason for poor training programs is lack of cooperation among some competent teachers and surgeons. Personal prejudices and petty jealousies have sometimes divided the efforts of several excellent teachers, with the result that none can provide an adequate teaching program, whereas, working together, they might offer excellent training. Prejudices born of self-interest and wounded pride have no place in the medical profession and could not exist if we adhered to the Golden Rule, the basis of medical ethics. The best interests of future orthopaedic surgeons demand that we submerge our wounded feelings and false pride in joint efforts to improve orthopaedic instruction in our respective communities.

A third cause of poor training is incompetent teaching. Unfortunately, there are some skilled surgeons who lack the ability to impart their knowledge to others. More often, however, the problem arises because the instructor has scarcely managed to qualify himself for certification and, therefore, is unable to "teach them this art . . . by precept, lecture, and every other mode of instruction". All too often such a teacher is the last to appreciate his own shortcomings and usually resents the fact that his service has not been approved for training. In such instances, in fairness to the trainees, it is clearly the unpleasant duty of the accrediting agencies to withdraw approval of such a service for training or to require that such men be replaced by others who are competent teachers as well as competent surgeons.

We should also recognize the fact that our teaching obligations are not limited to instruction of house officers and medical students. The results of orthopaedic treatment often depend upon services rendered to our patients by nurses, physical therapists, brace and artificial-limb makers, and others who work under our supervision. Unless these assistants have been exposed to good orthopaedic teaching and unless they work under sympathetic supervision, they cannot be expected to render their best services. Therefore, in order to secure the best results of orthopaedic care, it behooves each of us to devote as much time and energy as may be needed to provide adequate instruction and supervision for these essential helpers.

As a result of our expanded training programs, the number of qualified orthopaedic surgeons has increased rapidly since World War II, and there is evidence which indicates continued increases for some years to come. As of October 1950, there were 1,432 diplomates of The American Board of Orthopaedic Surgery. Nearly 300 applicants have been accepted for the Part II examination during the past few days. The 602 physicians who have successfully passed the Part I examination will undoubtedly appear for Part II during the next two or three years. In addition, 183 others have already filed applications for Part I, and an unknown number of orthopaedic residents are now in training. The rate of increase of orthopaedic surgeons is greater than that of the population as a whole, but as yet there has been no indication that our diplomates have encountered any great difficulty in acquiring practices which provide them with a livelihood. However, it is not surprising that some of our older members are beginning to wonder if our population will continue to absorb the increasing number of orthopaedic surgeons who are being trained. Obviously, there will be a point of saturation unless the orthopaedic field can be broadened to increase the demands for our services.

Research offers the best possibility for enlarging our field of endeavor. Investigation may uncover facts that will enable us to cure some conditions now considered hopeless. Certainly, present techniques will be improved, and more and more orthopaedic problems will be solved. During recent years there has been increasing interest in orthopaedic research in many of our teaching centers, and many of the papers and exhibits scheduled for this Meeting are reports of sound investigative work. However, the orthopaedic departments of too many of our medical schools do not sponsor any research whatever, although funds can usually be obtained for sound research projects which are competently supervised. So important is research to the future of orthopaedic surgery that we believe our Committee on Scientific Investigation should double its efforts to stimulate other centers to begin research work and to assist in obtaining the necessary funds and investigators to make this possible.

The underlying force that has carried us forward to our present vantage point is not to be found in our superficial relations to the rest of the field of medicine and to the public, but rather in the deeper motives, ideals, and traditions which govern us first as *physicians*, secondly as *surgeons*, and lastly as *orthopaedic surgeons*. As physicians, we are part of the American medical profession which, but yesterday, seemed secure in the scientific world and in the affections of the American public. Today, we tremble before what seems an almost overwhelming demand for compulsory governmental health insurance, which many believe will inevitably result in socialization and regimentation of our profession. Among the reasons advanced for this demand are an uneven distribution of physicians, rising costs of medical care, too many specialists, and too few general practitioners. Doubtless, all of these contribute to the present dissatisfaction of the public with medical care, but it is also possible that there has been a fundamental change in the attitudes of the medical profession itself, which may have an even more important bearing on the problem.

As *physicians* we subscribe to the principles of medical ethics, are bound by the Hippocratic oath, and have dedicated our lives to the care of the sick and injured, regardless of race, creed, or financial status; to the pursuit of knowledge, the furtherance of science, and the teaching of those who are to succeed. Faithful adherence to these ideals has set our profession above all others and has brought us to a position of eminence and respect. Unselfish devotion to these high moral and ethical traditions has increased our prestige, despite pestilence and war, revolutions, and economic and social upheavals. Now, as we stand upon what is thus far the highest peak of scientific achievement and material gain, the public which we serve points an accusing finger and says, in effect: "You do not give us the kind of care and help your fathers and grandfathers gave their patients. When we call for you, you make excuses on one pretext or another. When, perchance, we are duly referred and you give us your expert care, it is unduly expensive,

and we are heavily burdened or broken by the costs of illness. When our forefathers called for help, day or night, rain or shine, rich or poor, they could confidently expect your fathers and grandfathers to come and administer to their needs, in their homes, in the field, or by the roadside. Their visits often entailed great endurance and physical hardships; but they came to us, and their charges were never exorbitant or unreasonable."

Probably some such ideas, vague and unspoken as they often are, constitute the underlying cause for the rebuke which is now being given to our profession by the public, and which may carry with it the penalty of regimentation of our profession by non-professional politicians. Can it be that as the field of medicine has enlarged, as longer training has been required, and as specialization has increased, we have lost the unselfish spirit of service to the patient that characterized our profession fifty years ago? Have we permitted selfishness and the desire for material gain to replace the altruism which endeared our forefathers to their patients? Simply because we are highly trained and specialized orthopaedic surgeons, are we no longer bound by the ideals and traditions of service which have been the proud heritage of the medical fraternity? Surely the medical profession cannot afford to sell its birthright for a mess of pottage!

As *surgeons*, after having acquired understanding of the whole field of medicine, we strive to learn what diseases and injuries can be relieved or repaired by the judicious use of cutting instruments, and how to employ such measures without endangering our patients' lives. We must first master fundamental surgical principles. We must learn to evaluate the patient's ability to tolerate the cutting procedures indicated and to repair the wounds which we inflict. Without a background of knowledge of general medicine, surgical judgment would be faulty and the practice of surgery dangerous.

As *orthopaedic surgeons*, we have added to our knowledge of general medicine and surgery the application of orthopaedic principles for the treatment of crippling diseases and injuries. Orthopaedic measures—such as gradual stretching, manipulations, traction, splinting, and bracing—are employed for relief of articular pain and correction of deformities and other crippling conditions. These measures, when supplemented by well-executed surgical procedures, have enabled us to broaden our field of usefulness and to improve the results obtained in many cases. The best results in selected cases are secured by the judicious combination of one or more surgical procedures with consistent use of the time-honored orthopaedic principles of management during the preoperative and post-operative periods of treatment. However, probably more than half the crippling conditions which afflict mankind are amenable to non-operative orthopaedic measures alone, and these patients deserve as much thoughtful care from us as do those who, in addition, require some operative procedures.

Because operations are spectacular and, perhaps, because higher fees may be charged for such treatment, our residents often complete their training with distorted ideas of the importance of surgery in orthopaedics. They enter practice with but a vague conception of the application of orthopaedic principles in the care of the non-operative problems which confront us from day to day. Many trainees who have become proficient in the performance of spine fusions and arthroplasties of the hip are at sea when confronted with a case of painful flat-foot, chronic backache, or occupational strain. They often know little of brace designing and fitting or how to prescribe proper corrective shoes and corsets. This situation has developed because we, their teachers, are primarily interested in our more complicated operative problems and devote most of our teaching time to these, to the exclusion of the numerous ambulatory problems seen in our offices and in the out-patient clinics. Continued encouragement of such a trend can only result in narrowing our field of work and neglecting a large group of patients who have just claims upon us for special care. This neglected group must then turn more and more to cultists and irregular practitioners for help, and we shall be guilty of building the work of these practitioners while limiting our own field.

I have already indicated that we need to inform the public about the nature of our specialty, since many still confuse us with osteopaths, chiropractors, and podiatrists, and since there appears to be a need to broaden our field. The current trend of disseminating medical information through the medium of newspapers, magazines, radio, and television has been eagerly accepted by the public. Although a great deal of medical information regularly appears through these channels, little of it has pertained to orthopaedic subjects. Apparently the newspaper reporters and columnists are not being properly informed of our work. Articles related to the accomplishments of the specialty rather than those of individuals, or to programs of care rather than specific procedures, may be made interesting if they are properly written. Such writing should be planned by experts and should be closely supervised by committees with good judgment. Such an educational program of well-written ethical articles would require expenditure of funds, but is the way to educate the public regarding orthopaedic care.

A review of the entire list of orthopaedic organizations in this country is impressive. The American Orthopaedic Association with *The Journal of Bone and Joint Surgery* has been a dominant influence in the progress of orthopaedic surgery since 1889. The American Academy of Orthopaedic Surgeons, The American Board of Orthopaedic Surgery, the Orthopaedic Sections of the American Medical Association and the Southern Medical Association, the Central States and Western Orthopaedic Societies, and numerous other regional, state, and city groups and several travel clubs, all together constitute a valuable instrument for postgraduate education in our specialty. All are active and progressive. They provide good fellowship and a powerful stimulus for better orthopaedic surgery, but do they help *others* to know more about our specialty? Through them are we reaching general practitioners, general surgeons, and other specialty groups as we should? Are we attending meetings and reading the report of work from *other* specialties to glean from them the information which might help us in the diagnosis and care of our patients? Are we not, perhaps, becoming too self-centered, inbred, and dangerously content? Would it not be worth-while to make an organized effort to secure places on the programs of meetings other than our own and to publish articles in journals with wider circulations than ours? Much is already being accomplished in this direction by individual efforts of relatively few of us. Much more could be accomplished through organized planning and directed effort.

In concluding, I am grateful for the considerate attention you have given these somewhat random thoughts. If, in your judgment, they have any merit, they should not be casually passed over and quickly forgotten. They have been offered as constructive criticism of the current status of orthopaedic surgery, and, if only some of them are pertinent, these should be implemented for the advancement of our specialty. However, before this is done, there should be a much more comprehensive and objective survey of our activities and of our relations with other specialties. Such a survey might well be undertaken by a special committee composed of some of our members, together with an expert in the field of public relations. It would thus be necessary to invest some of our reserve funds in such a project. Your Executive Committee, before authorizing the expenditure of funds for such purposes, will want a mandate from the membership, requesting that such steps be taken. Therefore, if, by what I have said, you have been impressed with the possibilities for the betterment of our specialty, it will be in order for you to present and adopt a resolution at our next Executive Session, requesting appointment of a special committee which will give further consideration to the suggestions that have been made, and requesting your Executive Committee to give the necessary financial support to the project if your special committee, after due investigation, so recommends.

VASCULAR EPIPHYSEAL CHANGES IN CONGENITAL DISLOCATION OF THE HIP

Results in Adults Compared with Results in Coxa Plana and in Congenital Dislocation without Vascular Changes *

BY WILLIAM K. MASSIE, M.D., NEW YORK, N. Y.

From the New York Orthopaedic Dispensary and Hospital, New York

The existence of vascular impairment of the epiphysis following the reduction of a congenitally dislocated hip has long been recognized. Legg originally considered the epiphyseal changes to be quite distinct from those appearing in coxa plana (Legg-Calvé-Perthes disease), but in later years he considered them to be similar processes caused by a common etiological factor—trauma. Brailsford does not consider the two conditions "identical" because the phenomenon of mottling of the epiphysis occurs at different stages in the two disorders. Burrows without comment lists the two as synonymous. Ferguson and Howorth regard them as manifestations of the same condition in different age groups. Eyre-Brook noted some difference in the deformity resulting from the early changes, but took them to be similar processes. Gill formerly considered the rather frequent appearance of epiphyseal mottling or "fragmentation" following the reduction of congenitally dislocated hips as coxa plana, but more recently has believed it to be an aplasia of only mild prognostic importance. Only rarely does he call the condition true coxa plana. Recently Tucker has listed such changes as identical. Numerous observers have tabulated the incidence of the changes in their studies of congenitally dislocated hips, but have failed to explain the pathological nature of these changes. The condition has been variously termed "epiphysitis", "osteochondritis", "cystic degeneration", and "fragmentation" of the epiphysis.

TABLE I

Roentgenographic Results in Adults

Group	No. of Hips	Per cent. of Group Less than 60 Per cent. of Normal	Per cent. of Group 60 to 79 Per cent. of Normal	Per cent. of Group 80 to 100 Per cent. of Normal
Uninvolved and unsubluxated	7	0	0	100
Subluxated	27	66	22	11
Involved with vascular changes	21	72	14	14

The varying incidence of this condition as reported in the recent literature would seem to indicate a lack of agreement as to what constitutes a pathological vascular change evident in the roentgenogram, rather than a gross difference in results. (Crego and Schwartzmann, none; Severin, frequent; Ortolani, 2 per cent.; Leveuf, 23 per cent.; Ponseti, 46.2 per cent.; and Bost and his associates, 52 per cent. aseptic necrosis.)

The purpose of this report is to tabulate the early roentgenographic findings considered pathological in the light of subsequent adult deformities; to reiterate the significance of clinical findings at maturity, when compared with results in a group of fifteen adults with congenitally dislocated hips, but without vascular changes; to illustrate the

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 14, 1950.

TABLE II

INCIDENCE of ROENTGENOGRAPHIC VASCULAR CHANGES IN CONGENITAL DISLOCATION

No. Reduced	Method of Reduction	Hips Involved	
		Number	Per cent. of Group
58	Open	17	30
31	Closed	14	45

close similarity between congenital dislocation and coxa plana, and to compare the two conditions in the adult, both clinically and roentgenographically.

DEGREE AND INCIDENCE OF INVOLVEMENT

A study of the roentgenographic results of sixty-two * congenitally dislocated hips treated at the New York Orthopaedic Dispensary and Hospital prior to 1936 revealed that approximately 20 per cent. of these adults had a roentgenographic rating above 80 per cent. of normal. The remaining 80 per cent. presented changes which predisposed to the early development of degenerative arthritis. The method of grading the hips has been previously described [17]. The two factors primarily responsible for this abnormal development were a failure to maintain adequate reduction and the development of vascular changes of the epiphysis. It was found that 66 per cent. of the subluxated hips and 72

TABLE III

FEMORAL HEAD INDEX

Group	Average Range	Average Index
Normal adult	43 to 53	48
Congenitally dislocated, *uninvolved*	31 to 50	44
Congenitally dislocated, *involved*	11 to 40	29
Coxa plana	27 to 54	38

per cent. of the *involved* hips † had unsatisfactory end results (Table I). Each of the seven hips which remained unsubluxated and *uninvolved* by vascular changes had excellent results. Three subluxated hips had very good results. Each had minimal subluxation, indicated by widening of the medial joint space without upward displacement of the head. The three involved hips which showed very good results had minimal involvement; these will be discussed below (Grade I).

The prevention of subluxation is a technical problem, but treatment can be successful. The prevention of the epiphyseal changes depends on the elimination of a cause which is as yet unknown. These changes, then, would seem the most formidable sequelae in the treatment of congenital dislocation of the hip.

The incidence of roentgenographic vascular changes is disappointingly high (Table II). Thirty per cent. of the openly reduced hips and 45 per cent. of the hips reduced by closed manipulation showed such changes.‡ The figures include only those changes classi-

* Only fifty-four (Table I) of this number were available for this study, which includes all phases of development—two years after reduction, puberty, and adult life. Table II, on the other hand, includes twenty-seven hips reduced by the closed method which are not included in the sixty-two hips studied.

† *Subluxation* as herein used refers to any departure from the normal femoral head-acetabulum relationship. Thus any abnormal medial or horizontal joint-space widening has been tabulated as subluxation. *Involved* as used throughout this paper refers to congenital dislocation of the hip *with* vascular changes. *Normal* hips will be so designated; *uninvolved* is therefore not to be taken as meaning normal, but as referring to congenitally dislocated hips *without* vascular changes.

‡ A recent review of seventy-three hips reduced by both open and closed methods during the *past ten years* at New York Orthopaedic Hospital also reveals a 42 per cent. incidence of this condition.

fied below as "involved" hips; the mixed group discussed below is not included in this table.

MEASUREMENT OF DEFORMITY

Since the gradual replacement of avascular bone by osteoid tissue lowers resistance to pressure, and since the hip is a weight-bearing part, the deformity common to severe vascular changes of the hip is a flattening and broadening of the epiphysis. To compare the degree of deformity in different hips at various ages, it is desirable to have a unit of measurement of this deformity. Eyre-Brook effectively used the epiphyseal thickness divided by the epiphyseal width, expressed in percentage, as a unit of measurement in the child. In this study, this has been modified somewhat to apply to hips of all ages. It was noted by Wiberg that the circumference of the normal head or epiphysis above the age of three years subtends a portion of a perfect circle. The center or axis of rotation of the head can be easily determined by the use of an overlay (Fig. 1-A). The diameter of the head passing through this point in any plane should normally equal twice the radius meas-

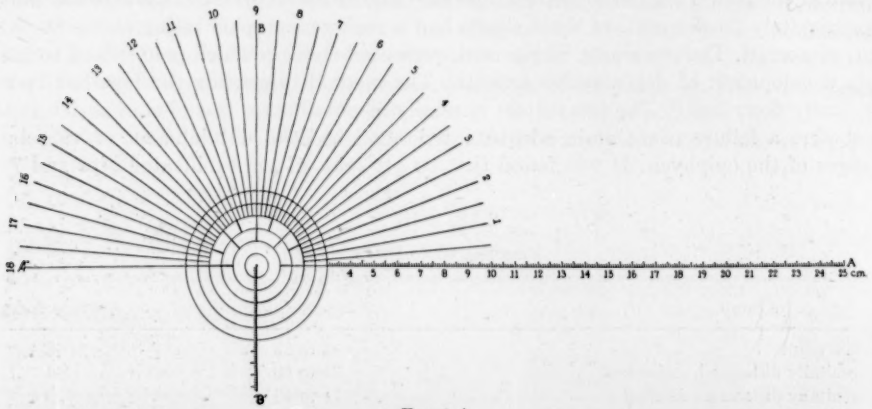


FIG. 1-A

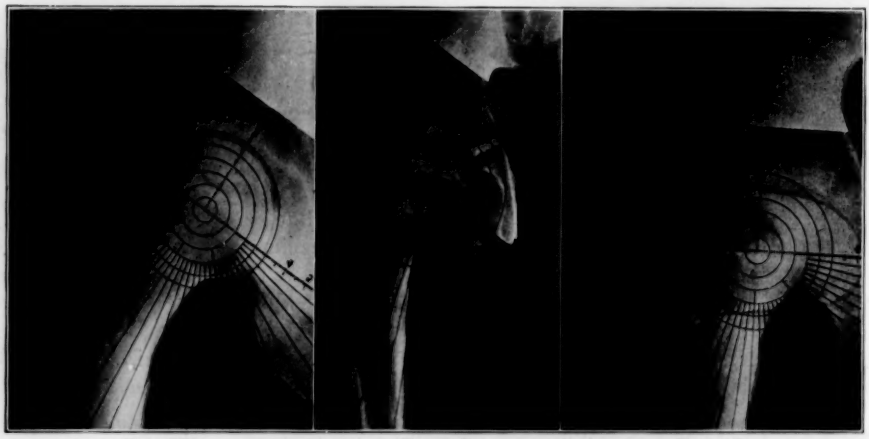


FIG. 1-B FIG. 1-C FIG. 1-D

Fig. 1-A: Measurement of head index. The overlay is so placed that the portion of the line AA′ representing the diameter of the largest circle coincides with the maximum diameter of the femoral head. The radius of the femoral head is measured on line BB′. (Circles are 5 millimeters apart.)

Fig. 1-B: Index here is $\frac{\text{Radius femoral head}}{\text{Diameter femoral head}} \times 100$ or $\frac{28}{56} \times 100 = 50$

Fig. 1-C: $\frac{12}{40} \times 100 = 30$.

Fig. 1-D: $\frac{24}{86} \times 100 = 28$.

ured in any plane. It may be expressed in a formula as follows: $\frac{\text{Radius of femoral head}}{\text{Diameter of femoral head}} \times 100 =$ a whole number which Eyre-Brook called the *head index*, and which is merely a percentage relationship of the radius to the diameter of the femoral head. When measuring a deformed head, the shortest radius and longest diameter passing through the center of rotation are chosen to express the maximum degree of deformity for that head. In the measurement of younger hips a gross error might be expected, since such a large percentage of the femoral head is cartilage and not visible on the roentgenogram. However, measurement of a representative series of hips of all ages before epiphyseal fusion gave an average index identical to that of 48 obtained in the normal adult series (Table III). This indicates that the ossified portion of the epiphysis after the age of three years assumes a normal spherical shape.

ROENTGENOGRAPHIC FINDINGS

Of sixty-two congenitally dislocated hips, forty-seven (75 per cent.) showed changes sufficiently suggestive of vascular disturbances to justify analysis. The series is easily separated into three distinct groups: uninvolved hips, involved hips, and a mixed group.

The uninvolved hips form 25 per cent. of the series. They at no time showed findings suggestive of any interruption in the vascular supply to the epiphysis (Figs. 2-A–2-F).

FIG. 2-A FIG. 2-B FIG. 2-C

FIG. 2-D FIG. 2-E FIG. 2-F

Figs. 2-A to 2-F: Congenital dislocation reduced by closed manipulation and uninvolved by vascular changes.

Fig. 2-A: Before reduction, at one and one-half years.

Fig. 2-B: At two years, adequate reduction has been maintained. Note the horizontal metaphyseal edge.

Figs. 2-C and 2-D: At four and a half and six and a half years of age. Roof obliquity has descended to normal. Epiphysis appears normal.

Fig. 2-E: At seven and two-tenths years. No deformity; gradual formation of a convex epiphyseal line.

Fig. 2-F: At twenty-three and one-half years of age; symmetrical head, normal roof obliquity, no premature arthritis.

FIG. 3-A FIG. 3-B FIG. 3-C

FIG. 3-D FIG. 3-E FIG. 3-F

Figs. 3-A to 3-F: Openly reduced hip involved with Grade I vascular changes.
Fig. 3-A: Roentgenogram just before reduction. Child is a year old.
Fig. 3-B: At one and one-half years of age, six months after reduction. Note mild subluxation, fragmentation of medial epiphyseal pole, rounding of medial edge of metaphysis.
Fig. 3-C: Two and one-half years after the reduction; epiphyseal fragmentation denotes partial absorption of the avascular medial half of the epiphysis, and early regeneration.
Fig. 3-D: Thirty months after reduction. Regeneration of epiphysis is progressing. Note normal development of medial metaphyseal edge.
Figs. 3-E and 3-F: At sixteen years. Appearance almost that of a normal hip. Note acetabular obliquity reduced to normal. Head index is 50.

The average roentgenographic rating of this group, measured by the method previously described [17], was 70 per cent. of normal.

FIG. 4-A FIG. 4-B FIG. 4-C

Figs. 4-A to 4-F: Openly reduced hip involved with Grade II vascular changes.
Fig. 4-A: Before reduction, at one and one-half years of age.
Fig. 4-B: At two years, after closed manipulation. Note epiphyseal changes, rounded metaphysis, and redislocation.

FIG. 4-D FIG. 4-E FIG. 4-F

Fig. 4-C: At three years of age, after open reduction. Marked degeneration of the epiphysis; failure of medial pole of metaphysis to develop; marked convexity of the epiphyseal line.

Fig. 4-D: Regeneration of epiphysis almost complete, with molding around the convex edges of the metaphysis. At seven years of age.

Fig. 4-E: Deformity still progressing. Epiphyseal line open. Thick short neck with flattening of the epiphysis at nine years of age.

Fig. 4-F: At eighteen years of age, grossly deformed "mushroom" head. Thickened acetabular floor with severe arthritis of both head and acetabulum.

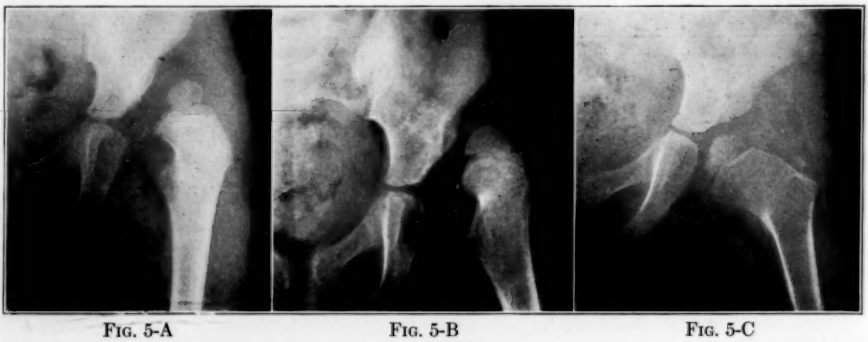


FIG. 5-A FIG. 5-B FIG. 5-C

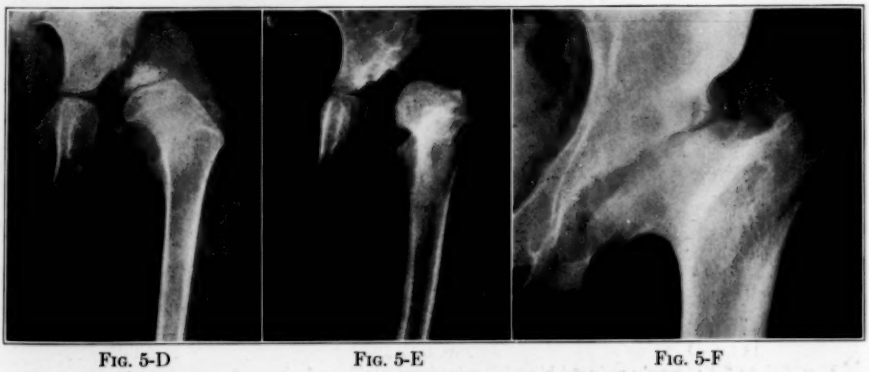


FIG. 5-D FIG. 5-E FIG. 5-F

Figs. 5-A to 5-F: Openly reduced hip involved with Grade III vascular changes.

Fig. 5-A: At two years. Note thick acetabular floor; complete dislocation, with false acetabulum; moderately severe roof obliquity.

Fig. 5-B: At two and eight-tenths years, three months prior to open reduction. Has been immobilized five months for reduction of opposite hip.

Fig. 5-C: Two weeks after open reduction. Epiphysis has normal appearance.

Fig. 5-D: Early vascular change in epiphysis and resubluxation. Open reduction was repeated next day.

Fig. 5-E: Nine months after second open reduction. Note complete loss of ossification of the epiphysis and resubluxation.

Fig. 5-F: At fifteen, flattening of neck parallel to the oblique acetabular roof. Epiphysis apparently never ossified. Severe arthritis.

The involved hip group forms 30 per cent. of the series and comprises those hips which in the early months after reduction showed changes in the epiphysis similar to coxa plana. The average roentgenographic rating of this group of adults was 45 per cent. of normal. There are three gradations of severity represented in the group. The salient roentgenographic findings of the three groups are listed:

Grade I

The mild or Grade I group (Figs. 3-A to 3-F) is characterized by:

1. The development of mild but definite convexity of the metaphyseal edge of the epiphyseal edge of the epiphyseal line;
2. Transient fragmentation of a portion of the epiphysis (usually the medial third);
3. Rapid disappearance of the fragmentation (after an average of one year), and resumption of a normally developing epiphysis after healing;
4. An adult head of almost normal conformity, with an average head index of 50.

This grade includes 10 per cent. of the involved hips, or 3 per cent. of the entire series.

Grade II

Grade II comprises 80 per cent. of the involved group, or 24 per cent. of the entire series. It is characterized by (Figs. 4-A to 4-F):

FIG. 6-A FIG. 6-B FIG. 6-C

FIG. 6-D FIG. 6-E FIG. 6-F

Figs. 6-A to 6-F: Openly reduced hip with mixed group, Type 1 changes.

Fig. 6-A: Before reduction, at three years of age.

Fig. 6-B: Nine months after reduction. Mild subluxation. Note medial epiphyseal flattening and rounding of medial metaphyseal lip.

Fig. 6-C: At five years of age, note absence of subluxation; medial epiphyseal flattening; medial metaphyseal edge poorly developed with convexity of epiphyseal line.

Fig. 6-D: At six and one-half years. No subluxation; no evidence of fragmentation of the epiphysis, as seen in Fig. 3-C.

Fig. 6-E: At eleven. Epiphyseal line narrow for this age. Note irregularity of superomedial portion of head, not coinciding with the acetabulum; mild coxa valga and shallow acetabulum.

Fig. 6-F: Twenty-two years. Further head irregularity and coxa magna. Subluxation has recurred, with an oblique acetabulum. Patient has mild arthritis.

FIG. 7-A FIG. 7-B FIG. 7-C

FIG. 7-D FIG. 7-E FIG. 7-F

Figs. 7-A to 7-E: Openly reduced hip with mixed group, Type 2 changes.
Fig. 7-A: Before reduction, at the age of one and one-half years.
Fig. 7-B: Adequate reduction shown at age of two years.
Fig. 7-C: At five years of age. Note resubluxation; mild medial flattening of the epiphysis, and straight horizontal epiphyseal line.
Fig. 7-D: At seven years. Note progressive medial epiphyseal molding and progressive coxa valga.
Fig. 7-E: At twelve years of age. Marked subluxation, but head deformity parallels irregular acetabular roof. Deformity probably due to abnormal mechanical pressure rather than to a vascular disturbance.
Fig. 7-F: At sixteen years of age. Note persistent subluxation, coxa valga, as well as marked arthritis and hypertrophy of lateral edge of acetabulum (external rotation of hip accentuates appearance of coxa valga).

1. The early development of marked convexity of the metaphyseal edge of the epiphyseal line, with very early deficiency in the formation of the medial lip;

2. Initial fragmentation of the ossified portion of the epiphysis, but without the uniform increased density common in coxa plana;

3. Occasional irregularity of the epiphyseal line, with central thinning of the epiphysis and the projection of the metaphyseal edge into the epiphyseal cap, characteristic of coxa plana;

4. Gradual flattening of the epiphysis, with extension around the medial pole of the metaphysis and often lateral extension to the base of the trochanteric epiphysis;

5. Gradual broadening of the metaphysis accompanied by shortening of the neck (metaphyseal osteoporosis and cyst formation usually absent);

6. Progressive development of deformity until epiphyseal fusion;

7. Occasional premature epiphyseal fusion;

8. Early development of degenerative arthritis after epiphyseal fusion.

The adult head in this group exhibits a variety of deformities, depending upon the severity of the vascular changes, the status of reduction of the hip and the development of the acetabular roof. Through serial roentgenograms, however, the primary deformity can be

demonstrated to occur in the femoral head. The acetabular changes are secondary. There are often irregularities in the head which do not coincide with the contiguous acetabular surface. Cystic degeneration is exhibited very early in a few hips and rapid progression of degenerative arthritis (Fig. 4-E) is the rule rather than the exception. The average adult head index for this group was 27.

Grade III

Grade III (Figs. 5-A to 5-F) comprises 10 per cent. of the involved hips and is characterized by:

1. The development of early and severe convexity of the metaphyseal edge;
2. Rapid dissolution of the ossific center of the epiphysis;
3. Failure of the epiphysis to regenerate;
4. Progressive flattening of the metaphysis, accompanied by severe subluxation;
5. Marked shortening of the femoral neck;
6. Development of the femoral weight-bearing surface from the molding of the metaphysis.

The complete destruction of the femoral head is noted at an early date, the result in the adult becoming quite poor, both roentgenographically and clinically.

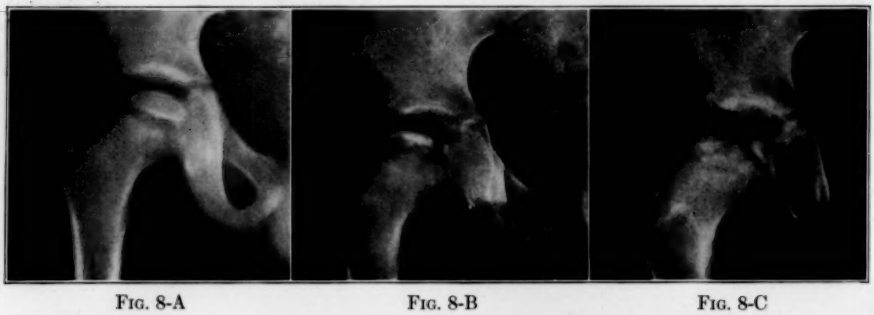


FIG. 8-A FIG. 8-B FIG. 8-C

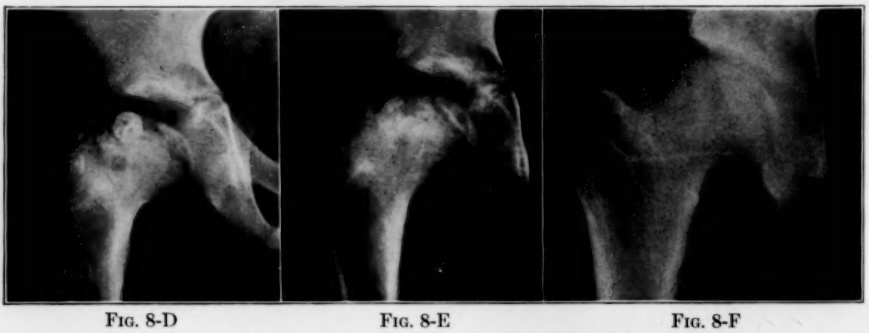


FIG. 8-D FIG. 8-E FIG. 8-F

Figs. 8-A to 8-F: Typical coxa plana treated by epiphyseal drilling and bed rest for one year.

Fig. 8-A: Note epiphyseal density, metaphyseal irregularity, and mild subluxation (joint-space widening). Drilling was done at five years of age.

Fig. 8-B: Progressive epiphyseal degeneration, metaphyseal osteoporosis and subluxation at five and one-half.

Figs. 8-C and 8-D: At six and seven and one-half years of age, the epiphysis is gradually regenerating with healing of metaphyseal changes. Some flattening of epiphysis and broadening of metaphysis. Note moderate convexity of epiphyseal line.

Fig. 8-E: At nine years of age, regeneration of both epiphysis and metaphysis is almost complete. Note subluxation persists, although it is slightly decreased.

Fig. 8-F: Moderately severe deformity, with head index of 32, at fifteen. Note smoothness of head and lack of degenerative arthritis.

FIG. 9-A FIG. 9-B FIG. 9-C

FIG. 9-D FIG. 9-E FIG. 9-F

Figs. 9-A to 9-F: Adult congenitally dislocated hips uninvolved by vascular changes or subluxation. Note symmetry of the head, minimal joint-line sclerosis. Abnormal acetabular development and slight irregularities of the head are the only residua of previous dislocation.

The Mixed Group

The mixed group is composed of hips showing early, definitely abnormal epiphyseal changes, but lacking the fragmentation of the epiphysis characteristic of both the involved group and of typical coxa plana. It forms 40 per cent. of the entire series. It is divided into two types.

Type 1 (Figs. 6-A to 6-F) includes hips which show no fragmentation of the epiphysis (in the films available), but which otherwise follow the same pattern of metaphyseal and epiphyseal changes throughout childhood and puberty seen in the involved group. All changes are, however, of less severity. This type forms 20 per cent. of the entire series and 50 per cent. of the mixed group. It is characterized by:

1. Convexity of the metaphyseal edge, which is the earliest and most constant finding. The convexity is due to the failure of the medial metaphyseal lip (which according to Walmsley eventually forms the medial inferior third of the adult head) to develop normally.
2. Thinning of the medial pole of the epiphysis, with molding around the deficient medial metaphyseal pole.
3. Failure of the neck to develop to a normal length.
4. Early development of degenerative arthritis.
5. An average adult head index of 38.

A general osteoporosis of the femoral head and acetabulum of several years' duration while the patients were ambulatory was noted in five of these hips. Fine cystic epiphyseal changes were often noted, which may have been apparent only because of the increased clarity of the trabeculations. Such changes were noted by Ponseti frequently enough to justify dividing the hips into a separate group. In a few instances the coalescence of the cysts seemed to contribute to the epiphyseal flattening.

FIG. 10-A FIG. 10-B FIG. 10-C

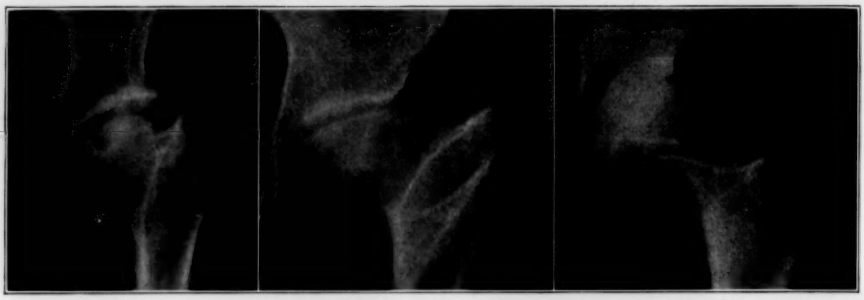


FIG. 10-D FIG. 10-E FIG. 10-F

Figs. 10-A to 10-F and 11-A to 11-F: Adult congenitally dislocated hips involved by vascular changes. Each hip shown also in the early active stage. Note the consistent lack of metaphyseal rarefaction and absence of mottling or "fragmentation" of epiphysis so commonly found in coxa plana. The severe adult deformities are not usually seen even in the more severe coxa plana cases. Note that the irregular head shape does not parallel the deformed acetabulum.

FIG. 11-A FIG. 11-B FIG. 11-C

FIG. 11-D FIG. 11-E FIG. 11-F

TABLE IV

INCIDENCE OF ARTHRITIS IN THE HIP JOINT

Group	15 to 19 Years (*Per cent. of Group*)	20 to 24 Years (*Per cent. of Group*)	More than 24 Years (*Per cent. of Group*)
Congenitally dislocated, *uninvolved*	0	0	50
Congenitally dislocated, *involved*	55	100	100
Coxa plana	25	75	50

Although widening of the neck is not noted, there may be widening of the base of the head as coxa magna develops.

The adult heads usually presented more deformity and irregularities than could be expected to result from molding against their respective acetabula in the presence of subluxation. Coxa magna is common, but there is a deficiency of the medial portion of the head, even when subluxation is present, which should reduce pressure against this portion of the head (Figs. 12-C to 12-E).

Type 2 is comprised of hips with adult results very similar to those of Type 1, but the early serial roentgenograms suggest that the deformity results from the molding of

TABLE V

INCIDENCE OF FUNCTIONAL DISABILITY

Group	Two Years after Treatment (*Per cent.*)	Adult (*Per cent.*)	Per cent. of Group with Hip Motion Less than 60 Per cent. of Normal
Congenital dislocations, *uninvolved*	15	30	15
Congenital dislocations, *involved*	85	95	70
Coxa plana	65	65	20

the femoral head against an oblique acetabular roof in the presence of moderate to severe subluxation (Figs. 7-A to 7-E). This type forms 20 per cent. of the entire series and is characterized by:

1. Early medial epiphyseal flattening, which in each case parallels an oblique acetabular roof;

2. The development of convexity of the metaphyseal edge so slowly as to be only slightly more rapid than in the normal hip;

3. Medial flattening of the adult femoral head, but with contours of the head and acetabular roof remaining parallel (coxa magna is not common);

TABLE VI

AGE INCIDENCE

Group	From 1 to 3 Years (*Per cent.*)	From 3 to 5 Years (*Per cent.*)	Over 5 Years of Age (*Per cent.*)
Congenital dislocations, *uninvolved*	55	20	25
Congenital dislocations, *involved*	33	17	50
Mixed group			
Type 1	0	57	43
Type 2	18	64	18
Coxa plana	0	0	100

TABLE VII
SEX INCIDENCE

Group	No. of Hips	Male (*Per cent. of Group*)	Female (*Per cent. of Group*)	Per cent. of Group with Bilateral Involvement
Congenitally dislocated, *uninvolved*	15	7	93	20
Congenitally dislocated, *involved*	21	33	67	30
Coxa plana	25	70	30	25

4. A head index average of 38;

5. Subluxation, present in 100 per cent. and severe in 85 per cent. of the hips in this grade;

6. Coxa valga, present in 50 per cent., which is considered normal.

The mixed group is perplexing. The hips so classified not only lack the classical roentgenographic signs of partial or complete avascular necrosis (epiphyseal density and fragmentation), but tend to divide into two sub-groups which are similar in most roentgenographic changes (Figs. 6-A to 7-E). However, a separate classification for this group is justified by the striking differences between these hips and those of the uninvolved group in all stages, particularly on the adult level (Figs. 9-A to 9-F and Figs. 12-A to 13-F). Definite deforming factors present in the mixed group were not apparent in the uninvolved group. In the latter the symmetry of the head approached normal, with an average index of 44. Though subluxation was frequent (66 per cent.), the femoral head showed none of

TABLE VIII
DURATION OF ACTIVELY PROGRESSING ROENTGENOGRAPHIC CHANGES

Group	Period of Progression		
	Less than 3 Years (*Per cent.*)	From 3 to 5 Years (*Per cent.*)	More than 5 Years (*Per cent.*)
Congenitally dislocated hips with vascular changes	15	20	65
Coxa plana	55	25	20

TABLE IX
COMPARATIVE SALIENT ROENTGENOGRAPHIC FINDINGS
(Expressed in grades of severity from 0 to 4)

Roentgenographic Findings	Grade of Severity in Congenitally Dislocated Hips, *Involved*	Grade of Severity in Coxa Plana
Density of epiphysis	1	4
Metaphyseal osteoporosis, either alone, or in combination with cyst formation	1	4
Fragmentation of the epiphysis	3	4
Medial metaphyseal lip deficiency	4	1
Premature convexity of metaphyseal edge	4	1
Broadening of metaphysis	4	4
Arthritis in the adult	4	2

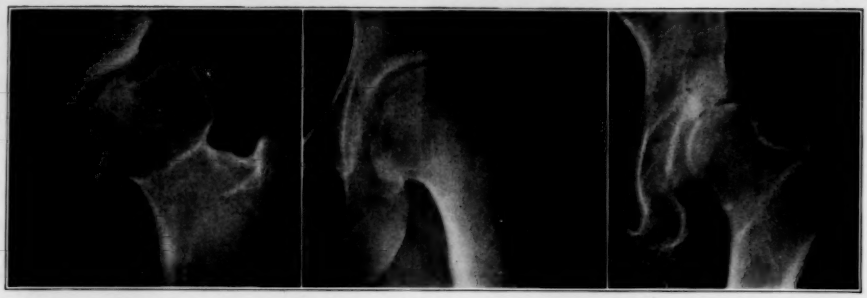


FIG. 12-A FIG. 12-B FIG. 12-C

FIG. 12-D FIG. 12-E FIG. 12-F

Figs. 12-A to 12-F: Adult hips of the mixed group Type 1. The head deformity does not appear to be due to pressure molding, since it is rarely parallel to the contiguous acetabular surface. Arthritis is moderate. Average head index is 38.

the molding changes noted in the mixed group. Therefore, the frequency of arthritic changes was materially lower. The justification for dividing this mixed group into two subgroups is based on the difference in prognosis in the two types and its relation to treatment. Both the clinical and the roentgenographic adult results of the Type 1 hips were inferior to those of Type 2. In some hips the dividing line is so fine as to be meaningless, but in others the differences mentioned above can be easily detected. It is postulated from the occasional appearance of irregular densities and molding of the epiphysis when no mechanical explanation can be justifiably made, that the Type 1 hips are the result of early partial epiphyseal vascular insufficiency. It is possible that more frequent roentgenographic studies might have clarified the issue. The Type 2 changes, on the other hand, probably result from mechanical pressure, because in each instance either the reduction had been done relatively late or resubluxation gave a convincing explanation for abnormal medial epiphyseal pressure. If this interpretation is correct, it is of some clinical importance, since control of the subluxation, if done promptly before the epiphysis has matured, may alter the prognosis.

COXA PLANA

To emphasize the importance of the epiphyseal vascular changes in congenital dislocation of the hip, and to point out similarities between the changes in this condition and those in coxa plana, a group of hips having typical coxa plana changes, unselected and followed to adult life, are compared with the hips of the involved group only. Since this is not a study of coxa plana *per se*, only those changes which have direct bearing on a comparison with congenital dislocation of the hip will be mentioned. A complete description of these changes has been reported by Howorth[12]. The principal roentgenographic changes in coxa plana (Figs. 8-A to 8-F) are listed below in the order of appearance.

1. General epiphyseal density with little or no flattening or interruption of the regular contour is the earliest roentgenographic finding.

2. Osteoporosis of the entire metaphyseal side of the epiphyseal line, which usually begins at the lateral edge, appears next. This is often accompanied by fine cystic changes which may coalesce into large cavities. The medial joint space is simultaneously appreciably widened.

3. There is gradual irregular epiphyseal absorption, and a roentgenographic appearance of mottling or "fragmentation", associated with widening of the metaphysis and development of epiphyseal plate convexity.

4. Rapid replacement and regeneration of the medial and lateral poles of the epiphysis are accompanied by healing of the metaphyseal changes.

5. The epiphyseal line often assumes a horizontal position, and its irregularity increases as it encroaches on the epiphysis centrally. In some hips the metaphysis extends up to the subchondral layer of the epiphysis.

6. The epiphysis gradually returns to normal homogeneous density, but in the great majority of hips there is detectable flattening of the contour.

7. Molding of the head in a subluxed position is occasionally accompanied by an oblique acetabulum closely resembling a congenital dislocation of the hip which has been incompletely reduced.

8. The subluxation or medial joint-space widening noted in 92 per cent. of the hips had been spontaneously reduced by the time the patient entered adulthood in all but 30 per cent. of the hips.

9. Premature fusion of the epiphyseal plate occurred in 65 per cent. of eleven hips of which roentgenograms were made frequently enough to determine this change. However, five of the seven hips which showed this change had been subjected to operative drilling of the epiphysis at various stages of the disease.

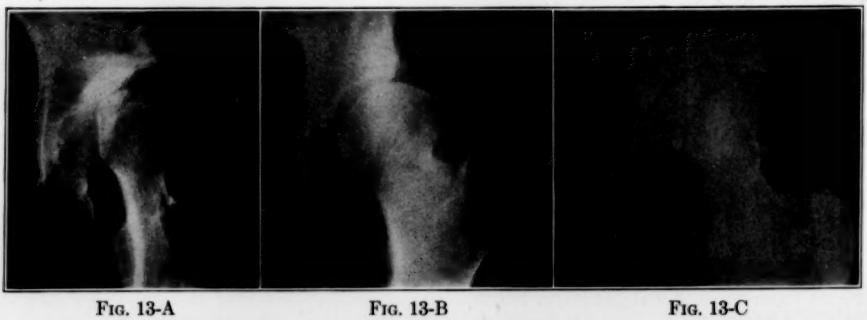


FIG. 13-A FIG. 13-B FIG. 13-C

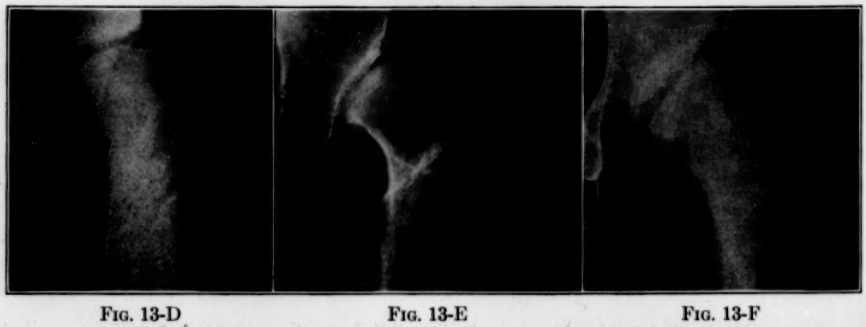


FIG. 13-D FIG. 13-E FIG. 13-F

Figs. 13-A to 13-F. Adult hips of the mixed group Type 2. The head deformity appears smooth and parallel to the contiguous acetabular surface. Note the severe subluxation. Average head index is 38.

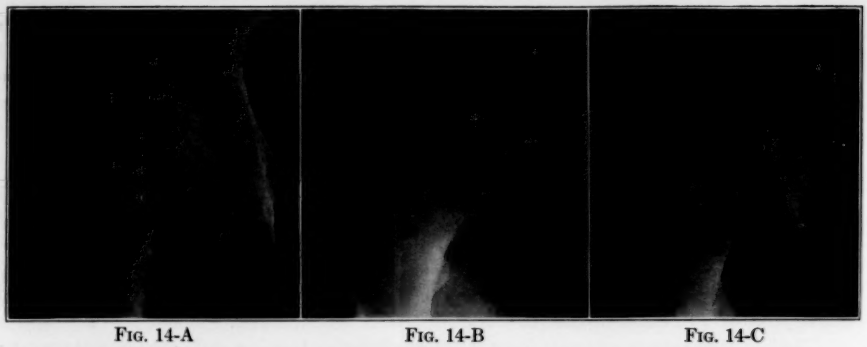


FIG. 14-A FIG. 14-B FIG. 14-C

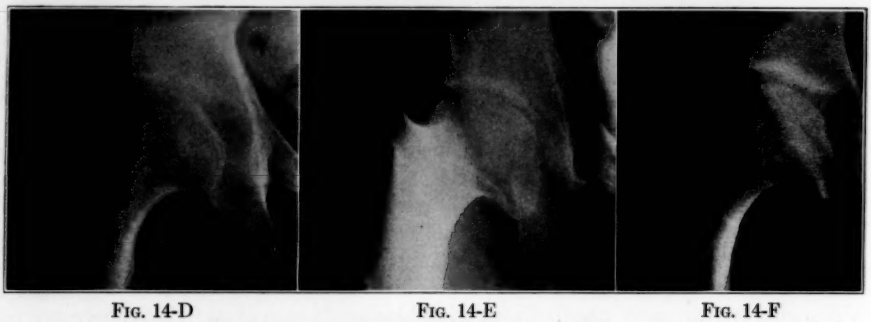


FIG. 14-D FIG. 14-E FIG. 14-F

Figs. 14-A to 14-F: Adult hips involved by coxa plana changes in childhood. All these hips underwent some form of treatment. Head deformity, though moderate, is smooth and parallel to the acetabular surface. Arthritis is not marked. Early subluxation has been reduced. Average head index is 38.

10. After maturity there is a gradual onset of marginal sclerosis, early lipping, and the cystic formation characteristic of degenerative arthritic changes. This was noted in 25 per cent. of the hips before the age of twenty years, but increased rapidly to from 50 to 75 per cent. after that age (Table IV).

GROSS PATHOLOGY

All but four of the congenitally dislocated hips were treated by open reduction; thus an opportunity was given to observe the appearance of the femoral head. Only one of the hips showed definite roentgenographic evidence of vascular changes prior to open reduction. On inspection, this hip appeared flattened medially, but this was also noted in hips appearing normal in the roentgenogram. Slight irregularities or depressions were noted in the cartilage which was otherwise smooth and of normal color. A number of the hips in the coxa plana group were exposed in various stages of the disease, the epiphysis being subjected to multiple drilling under direct vision. Though abnormal molding of the head was often noted, the cartilage seemed quite normal in appearance. No case showed evidence of cartilaginous degeneration.

COMPARATIVE STATISTICS

A comparison of the roentgenographic and clinical course of the involved congenital and coxa plana hips is summarized in Tables III to IX.

Patients examined two years after treatment had been discontinued showed easily discernible disability in 15 per cent. of the uninvolved congenitally dislocated hips, 85 per cent. of the involved hips, and 65 per cent. of the coxa plana hips. At this early date, then, a congenitally dislocated hip which is symptomatic following reduction is suggestive of vascular changes.

Occasional pain was noted in 10 per cent. of the uninvolved hips in adult life, 55 per cent. of the adult involved hips, and 40 per cent. of the coxa plana hips. Mild fatigue and some limitation of activity were common complaints of patients with involved congenitally dislocated hips as well as of those with coxa plana, but severe limitation of activity was present in none of the patients with uninvolved hips, 70 per cent. of those with involved hips, and 5 per cent. of the patients with coxa plana. Limp was absent in the patients with uninvolved hips but present in 55 per cent. of the involved patients and 35 per cent. of the coxa plana patients. The range of painless hip motion is a fairly accurate gauge of function (Table V). A range of less than 60 per cent. of normal was present in 15 per cent. of the uninvolved hips, 70 per cent. of the involved hips, and 20 per cent. of those with coxa plana. Only one patient with coxa plana had an associated positive Trendelenburg, but 40 per cent. of the involved hips were so classified.

The serial roentgenographic changes in the involved group differed from those of the coxa plana group in some respects (Table IX). The typical early metaphyseal rarefaction and occasional cystic changes in coxa plana are not seen in the involved hips. The epiphyseal flattening noted in the degenerative phase in coxa plana is not obvious in the group with congenital dislocation, probably because the absorption of the ossific epiphyseal center is much more rapid in the latter and hence cannot be demonstrated roentgenographically. The medial epiphyseal flattening mentioned by Eyre-Brook as characteristic of the vascular changes in congenital dislocation of the hip after reduction is more commonly seen in conjunction with severe subluxation and is generally considered to be caused by molding against an oblique acetabulum (Wolff's law) rather than by vascular changes. The development of a convexity of the metaphyseal edge of epiphyseal line normally takes place between nine and twelve years (this is evident from anteroposterior roentgenograms). Although it appears early in both the involved hips and in coxa plana, it develops much more rapidly in the former (Figs. 10-A to 11-F). It was noted that angulation of the epiphysis around the medial metaphyseal lip was quite constant and denoted early regenerative changes in the involved group (Figs. 10-A to 10-C, 11-A to 11-C). In the coxa plana hips the epiphysis overlapped both the medial and the lateral edges of the metaphysis (Figs. 8-D and 8-E).

Subluxation or widening of the medial joint space was noted in 92 per cent. of the coxa plana patients in the early stages, but this was reduced to 28 per cent. in adult life, while 75 per cent. of the involved hips remained subluxated. Possibly this fact contributed to the comparatively poor adult results in these hips. However, it must be noted that 66 per cent. of the uncomplicated congenitally dislocated hips showed some degree of subluxation, yet were both clinically and anatomically superior to the involved hips and to those in the coxa plana group.

Premature epiphyseal fusion was noted in one of the twenty-one involved hips, as compared with seven of eleven hips in the coxa plana group in which this point could be adequately assessed.

Table III indicates the comparative adult head index for the various categories studied. A rather comprehensive comparison can be made of the relative head deformity in the various groups. The hips of Grade II of the involved group had an average index of 29, the coxa plana group an average index of 38, the uninvolved hips an average of 44, and the adult normal hips an index of 48.

The age incidence (Table VI) indicates that a slightly higher percentage of the involved than of the uninvolved hips were initially reduced after the age of four years. This difference is certainly not impressive when it is considered that the degree of trauma is greater in a late initial reduction than in a reduction performed on younger patients. It is difficult to assess the importance, then, of the finding that 50 per cent. of the hips in the involved group and 50 per cent. of those in the coxa plana group were in the age group of five to eight years. The remaining 50 per cent. of the involved group were in children

of less than five years, and the remaining 50 per cent. of the hips in the coxa plana group were in children over eight years.

The sex incidence (Table VII) seems a more definitely influencing factor in the vascular changes of both congenital dislocation of the hip and coxa plana than does the age *per se*. Eighty per cent. of the congenitally dislocated hips in this series were in females, yet 33 per cent. of the involved hips were in males. Stated differently, 87 per cent. of the male congenitally dislocated hips and 25 per cent. of the female hips showed vascular changes. This indicates the same male sex preponderance as in coxa plana, where 70 per cent. were male and 30 per cent. female.

As noted in Table VIII, the actively deforming roentgenographic changes (excluding degenerative arthritic changes) progressed for more than five years in 65 per cent. of the involved hips but in only 20 per cent. of the coxa plana group (Figs. 4-A to 5-F). Since these changes rarely become static before epiphyseal fusion in either group, the prolonged activity and hence more severe deformities resulted in a lower age group for involved hips.

The latent period between the date of reduction of the congenital dislocation and the date of initial appearance of vascular changes cannot be tabulated, since, as has been stressed, these changes are gradual and are not apparent until three to twelve months after an operative or manipulative procedure. Maintenance of a set position in a cast, or even rapid mobilization following prolonged immobilization, may also be an initiating factor. Therefore any statement as to the length of time required for the roentgenographic recognition of these changes is grossly inaccurate at best. It must be reiterated, however, that, while these changes were not seen in hips not subjected to some form of active treatment, the interval between treatment and the time such changes appeared was so long that treatment hardly can be considered as the initiating factor.

The arthritis which developed in the adult involved group was considerably more severe than that seen in the coxa plana group. Minimal arthritis was considered present when there was dense sclerosis of contiguous portions of the head and acetabulum. Lipping and cystic degeneration with definite thinning of the joint space were graded as more advanced. In the age group under twenty years, approximately 55 per cent. of the involved hips showed arthritis in both the head and the acetabulum, as compared with 25 per cent. in the coxa plana group (Table IV). After twenty years of age, 100 per cent. of the involved hips and 50 to 75 per cent. of the coxa plana group showed arthritis. None of the uninvolved group of congenitally dislocated hips below twenty years of age, and 50 per cent. of those above that age, showed arthritis. Scrutiny of Figures 9-A to 14-F gives a fairly accurate impression of adult results in each of the groups represented. Figures 9-A to 9-F illustrate the routine result in congenitally dislocated hips reduced without the complication of either resubluxation or vascular changes. Figures 10-D, 10-E, 10-F and 11-D, 11-E, 11-F illustrate the results of Grade II changes noted in Figures 10-A, 10-B, 10-C, 11-A, 11-B, and 11-C. Figures 12-A to 12-F and 13-A to 13-F represent the obvious deformity which consistently results from early changes characteristic of the mixed group. The marked subluxation present in each of the Type 2 (Figs. 13-A to 13-F) hips should be noted. Figures 14-A to 14-F illustrate the average result obtained from the treatment of coxa plana at this institution two decades ago. Various methods of treatment are here represented, including bed rest, bed traction, epiphyseal drilling, and ambulatory sling. Though not good, these methods produce results superior to those noted in Figures 10-D, 10-E, 10-F, 11-D, 11-E, and 11-F.

DISCUSSION

Does the roentgenographic appearance of the involved congenital hips indicate a pathological process identical to that of coxa plana? Any condition which appears irregularly in a series of cases, and which persists and results in a progressive deformity, must

be considered pathological. Any variant stage of normal, then, must be excluded by the adult roentgenogram of these involved hips. Though the author is not aware of a pathological report of an epiphysis which exhibited such roentgenographic changes following reduction of a congenital dislocation, the similarity in appearance and behavior of the involved congenital hips and those with coxa plana strongly suggests a common pathological basis. It seems well substantiated by both animal experiments and pathological examination of human specimens that the coxa plana changes are on a vascular basis [26, 8, 13, 25]. It is presumed, therefore, that similar changes noted in congenitally dislocated hips are also of a vascular nature.

The etiology of these vascular changes is unknown. Albright has demonstrated that the roentgenographic appearance of the femoral epiphysis of a cretin at times can simulate those described above, but the numerous associated clinical findings are absent. Other conditions such as rickets, Morquio's disease, and chondrodystrophy may at times simulate these femoral-head changes. The role of subclinical vitamin or hormone deficiency cannot be excluded on the basis of our present knowledge. Any of these factors could conceivably be the sole cause of epiphyseal changes, but it would still be difficult to explain the fact that the sex incidence is predominantly male, the rather consistent age incidence in coxa plana, or the association of such changes in congenitally dislocated hips with the trauma of reduction.

Certain observations brought out in this and other reports suggest yet another possible etiological factor. Varying degrees of trauma are inevitable in the reduction and plaster fixation of a dislocated hip after the age of one year. Yet careful observation has failed to demonstrate unusual trauma in those hips showing vascular changes. The closed and the open methods of reduction seem almost equally effective in producing this sequela. The individual effect of manipulation, position in plaster after reduction (abduction and internal rotation short of the extremes), and various operative measures were given due attention, but none could be singled out as playing the major role in the occurrence of these changes. The incidence among skilled operators was comparable. Trauma, *per se*, would then seem an unlikely explanation. The high male sex incidence common to both the coxa plana series and the congenitally dislocated hip series would also tend to minimize the role of trauma. Yet all of these facts tend to blend into a logical postulate which is supported by anatomical studies of the vascular pattern of the hip. It is postulated that there exists a congenital predilection for vascular damage dependent upon the relatively insufficient vascular arrangement in some hips. Every careful study of the minute vascular supply has emphasized the marked individual variation. Variations relative to sex, however, have not been reported. The rather high incidence of bilateral involvement (47 per cent. in the congenital hip series; 25 per cent. in the coxa plana series) would also support the above hypothesis.

If such a postulate is subsequently substantiated by facts, the inconsistent role of trauma can be easily explained. There are degrees of trauma severe enough to produce such vascular changes in every case, and this has been substantiated by animal experiment [13]. Clinically this is supported by the very high incidence of these changes noted when the application of real force in closed manipulation was in vogue. At the other extreme, such changes have been noted when no abnormal trauma had been sustained. Only 20 per cent. of the coxa plana group gave a history of even mild trauma. In such cases trauma serves only as an initiating factor. The local vascular condition of such a hip might be similar to the general vascular condition of a child with congenital heart disease fully compensated until overactivity causes decompensation.

The postulate can be correlated with the facts anatomically. The work of Wolcott, recently substantiated by Tucker, indicates that the ligamentum teres only occasionally supplies the epiphysis with a substantial blood flow in the first years of life. This was supported by Howorth, who found only one freely bleeding ligamentum teres vessel in approx-

imately 185 open reductions at which he was present. However, relatively little blood is required by the infant femoral head composed of so high a proportion of cartilage. But as the proportion of cartilaginous matrix to ossified matrix decreases, the blood requirement increases. When the vascular supply lags behind the increasing demand, the stage is set for an acute vascular deficiency to follow even mildly aggravating circumstances such as slight trauma. It is apparent that during the first three years of life the vascular demand of the femoral head is low, and vascular insufficiency is brought about only by comparatively severe trauma (manipulative or operative reduction). Gradually, however, the proportion of cartilage decreases and the vascular demand increases, and this change is paralleled by the rising incidence of coxa plana in children between four and eight years. The high male sex incidence would suggest an inherent vascular insufficiency.

The metaphyseal convexity in the congenitally dislocated hip group, and the osteoporosis and cystic changes in the metaphyses of the coxa plana group, also support the postulation of a common etiological factor. Recently Haythorn described the cystic metaphyseal areas of coxa plana as consisting of dense fibrous tissue with some giant-cell reaction. No inflammatory reaction was noted. A decrease in vascularity usually results in fibrosis. It is known that both the capsular and nutrient arteries supply branches to the actively proliferating metaphyseal area of the femoral neck. When vascular insufficiency ensues, it is portrayed in the younger congenitally dislocated hip by deficiency of the medial or inferior portion of the ossified metaphyseal line. Severe deficiency is associated with epiphyseal changes, but minor deficiency results only in retarded ossification of the medial metaphyseal lip; this is responsible for the roentgenographic appearance of the mixed group. In the corresponding age group with coxa plana this same vascular deficiency results in generalized metaphyseal fibrosis with some cystic formation. The increased density noted in the epiphysis is not seen in the metaphysis because the vascular supply from the nutrient artery has remained unaffected by the initiating factor and continues to partially supply the metaphysis. As the age of the individual increases and the artery of the ligamentum teres begins to become effective, the incidence of coxa plana decreases.

None of the patients with congenitally dislocated hips was treated for the vascular changes *per se*. If, however, these changes are identical to those in coxa plana, it might be expected that a period of freedom from weight-bearing would result in rapid regeneration with minimal deformity, since it is well recognized that the younger the coxa plana patient at the time when weight-bearing is prohibited, the more rapid and complete is the regeneration.

SUMMARY

The poor results in the treatment of congenital dislocation of the hip stem either from resubluxation after reduction or from the onset of vascular changes in the epiphysis. The former is preventable by treatment. The occurrence of vascular changes in hips reduced after the age of one year, however, at present is neither predictable nor preventable. In the series reported, 35 per cent. showed definite vascular changes and another 20 per cent. had a roentgenographic appearance indicating partial involvement; in seventy-two of the hips involved by such changes adult results were unsatisfactory. Clinically these patients are distinguishable by persistent symptoms at an early age. The changes are considered identical to those of coxa plana manifested at an earlier age. When left untreated, however, they result in more severe adult deformity. A comparably high male sex incidence was noted in both groups of hips. A susceptibility to vascular injury is postulated on the basis of individual variations in the vascular supply to the femoral head. The importance of early recognition for treatment of this disorder cannot be stressed too much. The method of treatment advocated at this time is prohibition of weight-bearing until the head appears healed roentgenographically.

REFERENCES

1. Albright, Fuller: Changes Simulating Legg-Perthes Disease (Osteochondritis Deformans Juvenilis) Due to Juvenile Myxoedema. J. Bone and Joint Surg., **20:** 764–769, July 1938.
2. Bost, F. C.; Hagey, Helen; Schottstaedt, E. R.; and Larsen, L. J.: Results of Treatment of Congenital Dislocation of the Hip in Infancy. J. Bone and Joint Surg., **30-A:** 454–468, Apr. 1948.
3. Brailsford, J. F.: Avascular Necrosis of Bone. J. Bone and Joint Surg., **25:** 249–260, Apr. 1943.
4. Burrows, H. J.: Coxa Plana. With Special Reference to Its Pathology and Kinship. British J. Surg., **29:** 23–36, 1941.
5. Crego, C. H., and Schwartzmann, J. R.: Follow-up Study of the Early Treatment of Congenital Dislocation of the Hip. J. Bone and Joint Surg., **30-A:** 428–442, Apr. 1948.
6. Eyre-Brook, L.: Perthes Disease, The Results of Treatment by Traction in Recumbency. British J. Surg., **24:** 166–182, 1936.
7. Ferguson, A. B., and Howorth, M. B.: Coxa Plana and Related Conditions at the Hip. J. Bone and Joint Surg., **16:** 781–803, Oct. 1934.
8. Gall, Edward A., and Bennett, G. A.: Osteochondritis Deformans of the Hip (Legg-Perthes Disease) and Renal Osteitis Fibrosa Cystica. Arch. Pathol., **33:** 866–878, 1942.
9. Gill, A. B.: End Results of Early Treatment of Congenital Dislocation of the Hip. J. Bone and Joint Surg., **30-A:** 442–453, Apr. 1948.
10. Haythorn, S. R.: Pathological Changes found in Material Removed at Operation in Legg-Calvé-Perthes Disease. J. Bone and Joint Surg., **31-A:** 599–611, July 1949.
11. Howorth, M. B.: Congenital Dislocation of the Hip. Ann. Surg., **125:** 216–236, 1947.
12. Howorth, M. B.: Coxa Plana. J. Bone and Joint Surg., **30-A:** 601–620, July 1948.
13. Kistler, G. H.: Effects of Circulatory Disturbances on the Structure and Healing of Bone. Injuries of the Head of the Femur in Young Rabbits. Arch. Surg., **33:** 225–247, 1936.
14. Legg, A. T.: An Obscure Affection of the Hip Joint. Boston Med. and Surg. J., **162:** 202, 1910.
15. Legg, A. T.: The End Results of Coxa Plana. J. Bone and Joint Surg., **9:** 26–36, Jan. 1927.
16. Leveuf, Jacques: Results of Open Reduction of "True" Congenital Luxation of the Hip. J. Bone and Joint Surg., **30-A:** 875–882, Oct. 1948.
17. Massie, W. K., and Howorth, M. B.: Congenital Dislocation of the Hip. Part I. Method of Grading Results. J. Bone and Joint Surg., **32-A:** 519–531, July 1950.
18. Massie, W. K., and Howorth, M. B.: Congenital Dislocation of the Hip. Part II. Results of Open Reduction as Seen in Early Adult Period. J. Bone and Joint Surg., **33-A:** 171–190, Jan. 1951.
19. Massie, W. K., and Howorth, M. B.: Congenital Dislocation of the Hip. Part III. Pathogenesis. J. Bone and Joint Surg., **33-A:** 190–198, Jan. 1951.
20. Ortolani, Marino: La lussazione congenita dell'anca. Nuovi criteri diagnostici e profilattico-correttivi. Bologna, Capelli, 1948.
21. Ponseti, Ignacio: Causes of Failure in the Treatment of Congenital Dislocation of the Hip. J. Bone and Joint Surg., **26:** 775–792, Oct. 1944.
22. Severin, Erik: Congenital Dislocation of the Hip Joint. Acta Chir. Scandinavica, **84:** Supplementum 63, 1941.
23. Tucker, F. R.: Arterial Supply to the Femoral Head and Its Clinical Importance. J. Bone and Joint Surg., **31-B:** 82–93, Feb. 1949.
24. Walmsley, Thomas: The Epiphysis of the Head of the Femur. J. Anat. and Physiol., **49:** 434–440, 1915.
25. Wiberg, Gunnar: Studies of Dysplastic Acetabula and Congenital Subluxation of the Hip Joint. With Special Reference to the Complication of Osteo-Arthritis. Acta Chir. Scandinavica, **83:** Supplementum 58, 1939.
26. Wolcott, W. E.: The Evolution of the Circulation in the Developing Femoral Head and Neck. Surg., Gynec., and Obstet., **77:** 61–68, 1943.
27. Zemansky, A. P.: Legg-Calvé-Perthes' Disease. (Osteochondritis Juvenilis Deformans Coxae.) Am. J. Surg., **4:** 169–184, 1928.

DISCUSSION

Note: This Discussion includes that of "Late Results in Legg-Perthes Disease", by Eugene R. Mindell, M.D., and Mary S. Sherman, M.D., which was published in the January 1951 issue of *The Journal* (33-A: 1–23).

Dr. Leo S. Lucas, Portland, Oregon: Dr. Massie feels that there is a predisposition for vascular changes in hips of children with congenital dislocation and coxa plana. His paper presents excellent arguments in favor of this hypothesis, although it is difficult to substantiate it clinically in the light of our present knowledge. Perhaps a technique will be developed whereby arteriograms on the living subject may be perfected, so that circulation in the normal hip may be compared with that in the affected hip and give us a definite answer to the problem. We feel definitely that our results would have been much better in our early cases had we prevented weight-bearing upon the hips with vascular changes. Our recent summary of involved hips followed for ten to twenty-five years at the Shriners' Hospital closely approximates the results obtained by

Dr. Massie. Positioning and maintenance of the head in the acetabulum throughout the whole period of immobilization is of paramount importance.

We feel that coxa valga rarely exists and that hips which appear to show signs of this condition are usually cases of anteverted heads. This can be proved by roentgenograms of the whole femur. When the thigh is forcibly rolled inward, the roentgenogram will usually show a normal angle between the shaft and neck and head of the femur, but the lower femoral condyle will be in the lateral plane. Therefore, proper reduction can only be maintained by marked internal rotation of the leg. After a few months this should be corrected. This should be done by subtrochanteric osteotomy rather than by supracondylar osteotomy, to exclude the pull of the glutaeus maximus. We have found that this muscle can cause redislocation, due to its anterolateral position on the femur after reduction by internal rotation. This is probably the reason why some hips become resubluxated when the osteotomy is performed in the lower third of the femur.

We agree with the authors that in coxa plana a perfect hip is almost never achieved, particularly in terms of roentgenographic appearance. Our follow-up studies of hips treated by non-weight-bearing show much better results, but it is too early to make any definite statement as to how much superior these results will prove to be. Early changes in the neck and spreading out of the head appear to be the prelude to pronounced anatomical changes, with early functional disturbances and marked arthritic changes soon to follow. In making a study of the results in Perthes' disease, it is essential to wait until the epiphysis is closed and for some years thereafter. The authors have followed their cases sufficiently long to draw conclusions of value in the study of this interesting disease. I wish to thank the authors for these most stimulating and instructive papers.

Dr. Clarence H. Heyman, Cleveland, Ohio: Dr. Massie shows that the incidence of head changes after open reduction of congenital dislocation of the hip is not significantly less than after closed reduction. This is an important observation. It supports my own conclusions that avascular changes in the head are a consequence of reduction, and that the trauma of manipulation *per se* does not appreciably damage the circulation to the head. Whatever the cause of these head changes, it is something which appears to operate only after the hip has been reduced. Dr. Massie believes that the changes in congenital dislocation and Legg-Perthes disease are identical processes, although he has found that the essential changes upon which we base a diagnosis of Legg-Perthes disease are not found in congenital dislocation. The short latent period between reduction and the initial head changes, three to twelve months, indicates that there is a definite cause-and-effect relationship between these changes and reduction, and that the changes cannot be explained as a delayed reaction occurring during the age group when the incidence of Legg-Perthes disease is highest. Although the acetabular changes in Legg-Perthes disease are secondary to changes in the head, I do not believe this is true in congenital dislocation. On the contrary, abnormality of the acetabulum occurs concomitantly with congenital dislocation and frequently is found to be the predominant abnormality. If the head changes in both conditions were the same process, manifested differently according to age, Legg-Perthes disease would also be more common in girls. Legg-Perthes disease and slipped epiphysis may be so related, but I doubt that this is true of congenital dislocation. I do not believe the head changes in congenital dislocation are necessarily caused by a primary and inherent vascular deficiency beyond all control and of common origin with that in coxa plana. If this were true, the two conditions would occur spontaneously with comparable frequency in the unreduced hip, and one would have to adopt the fatalistic attitude that deformity of the head will or will not occur regardless of the method used or the time of initial treatment. I believe avascular changes are secondary to some other factor, such as pressure, and are preventable to a considerable degree by early reduction and by methods such as preliminary traction, which minimize intra-articular pressure subsequent to reduction. The earlier the reduction, the less the pressure, and the greater the likelihood of a stimulation toward normal growth and development in the acetabulum as well as in the head.

Dr. Mindell and Dr. Sherman's paper was not made available before this reading; I had their conclusions only. It has been my practice to keep these children in bed with traction for several months, or until the roentgenograms show beginning regeneration, and then to institute ambulatory treatment with the protection of an ischial weight-bearing brace until regeneration is well advanced. I have an open mind regarding the necessity of this but intend to continue along these lines until a comparable series of cases treated by less confining methods shows results just as good or better. Other than that the prognosis is better in children under six years of age, I can find nothing reliable to indicate what the end result will be.

I agree that practically never does a perfect hip result, but there are a large number of hips so near normal that it is difficult to detect abnormality without comparing the roentgenograms of the two hips. I have a large number of slides showing hips almost normal. We shall run through these quite rapidly. You will observe that these are all very good hips, that several had marked changes in the neck and a flat epiphysis early in the course of the disease, but showed excellent final results. In none has there been a premature closure of the epiphyseal plate.

Dr. Mary S. Sherman (closing): There are just two points that I would like to make. The first is that we found it extremely difficult to grade these patients with Legg-Perthes disease because the differences be-

tween them, as judged clinically and on the roentgenogram, were often so slight. However, there is no question about the fact that the patients who were treated early did infinitely better than, and differed greatly from, those patients who were treated late or who were not treated at all. There is also no question that those patients who were treated by ambulatory methods and those patients who were treated by non-ambulatory methods showed no difference whatever in the final result.

The only other thing I would like to add is a word of caution about judging end results at a time when the epiphyses of the femur are still open. We have several times seen a hip which appeared to have a good end result suddenly change when the child reached a period of rapid growth, so that even two or three years after the disease appeared arrested, there was a sudden increase in deformity of the head and neck, which made the final result quite different from what one would have expected two years before.

I would like to thank the discussors for their kind attention.

DR. WILLIAM K. MASSIE (closing): I would like to thank my discussors, Dr. Lucas and Dr. Heyman, for their kind remarks. Dr. Lucas mentioned anteversion as a possible etiological factor in vascular changes. I am grateful that he warned me in time to look up the correlation of anteversion with these changes, since I had not previously compiled these figures. Of twenty-one hips with vascular changes, fourteen had definite and moderately severe anteversion, two were of questionable severity, and in five anteversion was not recorded. Nine of the fourteen hips with moderately severe anteversion subsequently had osteotomies which were performed within six weeks after the original reduction. In other words, 66 per cent. were known to have anteversion. Of the hips known to be uninvolved with vascular changes, 84 per cent. also had appreciable anteversion. From these figures it would be difficult to draw a conclusion concerning the correlation of the two conditions. Coxa valga was noted regularly when there had been persistent prolonged subluxation, moderate or severe. We agree with Dr. Lucas that anteversion does result in apparent coxa valga and that anteroposterior roentgenograms taken of hips in full internal rotation give the only accurate measurement of this condition. This was not possible in these cases, since they were all treated a number of years ago. However, in each case in which moderate or severe anteversion was present, an osteotomy had been done to eradicate it, and therefore a routine anteroposterior view at a later date, showing coxa valga in comparison to the normal side, probably did indicate a true change in the angle of inclination.

Dr. Heyman considers the vascular changes of the femoral head as secondary to the reduction rather than primary. We are in complete agreement, since we believe that these changes are rare when treatment has not been given. However, if Dr. Heyman explains these changes by the trauma of reduction alone, then we are in disagreement. None of the variables of treatment could be consistently correlated with these changes. Severe trauma such as that caused by the Lorenz type of manipulation formerly resulted in a high incidence of vascular changes, but when all cases are treated by an identical routine with emphasis on gentleness, variable results are difficult to attribute to trauma alone. Nor could we explain the marked difference in sex incidence on the basis of trauma alone. This intangible factor then, we have considered as an inherent anatomical vascular variation. Those hips with a not too abundant vascular supply were more susceptible to trauma. We postulate that the same factor explains the rather erratic appearance of coxa plana, which is often not related to severe trauma.

Dr. Heyman's reluctance to accept these vascular changes as identical with those in coxa plana is certainly justified. We are unaware of any pathological studies which can support our contention that these changes represent identical processes operating at different age levels in the development of the hip. Yet the similarities in the early roentgenographic appearance and in the progressive deformities, and the common high male sex incidence seem rather suggestive. Also we are unable to explain these changes in congenitally dislocated hips on a basis other than of a vascular nature. The vascular basis of changes in coxa plana seems to have been adequately demonstrated by pathological data. However, the relationship between these two conditions cannot be established with the data at hand.

The pertinent fact in this study is that apparently benign epiphyseal and metaphyseal changes noted in congenitally dislocated hips result in progressive deformity in 90 per cent. of the hips so involved, with 70 per cent. of these showing an adult result far worse than the average result in coxa plana.

FOLLOW-UP STUDY OF THE USE OF REFRIGERATED HOMOGENOUS BONE TRANSPLANTS IN ORTHOPAEDIC OPERATIONS *†

BY PHILIP D. WILSON, M.D., NEW YORK, N. Y.

From the Hospital for Special Surgery, New York City

This report is intended to be the complement of an earlier paper, entitled "Experiences with a Bone Bank", which I read before the American Surgical Association at its Annual Meeting at Hot Springs, Virginia, in April 1947. In that paper, I gave a summary of experience at the Hospital for Special Surgery with the use of homogenous bone grafts which had been preserved by refrigeration at temperatures of between minus 10 and minus 20 degrees centigrade, for varying periods of time, and then used as a substitute for grafts of fresh autogenous bone in orthopaedic operations. While the experience was small, covering a period of only one year beginning May, 1946, and comprising thirty operations on twenty-five patients, the results appeared to be so satisfactory that it was considered justifiable to publish a preliminary report. Since that time we have continued to use this method of bone transplantation almost to the exclusion of autogenous bone grafts, and it seems important to make an additional report based on this much longer and larger experience.

Contemporary Work with Homogenous Grafts

In my former paper, I gave a summary of the previous efforts to find substitutes for autogenous bone grafts, of experiments with various materials, and of the results obtained. Here I shall comment only on those articles dealing with the subject which have appeared since that time.

In 1947, L. F. Bush published a preliminary report on the use of homogenous bone grafts from seventy-three donors in sixty-seven operations at the New York Orthopaedic Hospital. Some of the grafts were obtained from relatives of the patients (syngenesious) and were used immediately, while others were homogenous and had been preserved by implantation under the patient's skin or by refrigeration at minus 25 degrees centigrade for various periods of time in sterile glass jars. A table of the various conditions treated is shown, but there is no summary of the results or any figures indicating the number of grafts implanted by each of these three methods. The results are described as satisfactory. M. O. Henry, in 1948, reported some cases of lesions of the long bones treated by fresh syngenesioplastic bone grafts. In some cases the lesions recurred, but were finally cured by re-operation. Reynolds and Oliver, in 1949, reported on the use of homogenous bone grafts which had been preserved in an aqueous solution of merthiolate. The strength of the solution in which the bone was immersed for the first two weeks was 1:1000; thereafter, it was kept in a solution of 1:5000 which was changed every two weeks until the bone was used. They reported follow-up studies in forty-two patients with six failures; in one case the bone was extruded. In these patients, healing was slower than it would have been had fresh, autogenous grafts been used. Weaver used refrigerated, homogenous grafts which had been obtained from amputated limbs or from fresh cadavera. For the most part, these were used as massive, onlay grafts in the treatment of ununited fractures. Aside from several infections, which were the result of an imperfect technique in the early part of the work, good results were obtained.

The experience at the Hospital for Special Surgery up to April 22, 1949 covers a

* Read at the Annual Meeting of The American Orthopaedic Association, Colorado Springs, Colorado, May 19, 1949.

† Received for publication May 13, 1950. Illustrations received December 1, 1950.

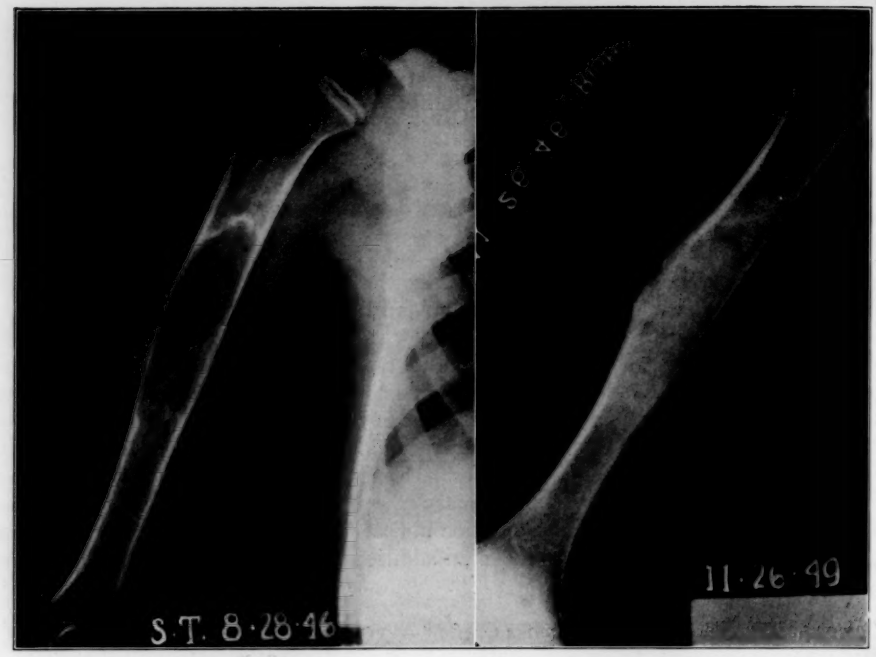


FIG. 1-A Fig. 1-B

The patient, a boy of eleven years, was admitted to the Hospital for Special Surgery in September 1946, with recurrent osteitis fibrosa cystica of the humerus. He had been operated upon in November 1938; the cyst had been curetted and the cavity packed with autogenous bone chips from the tibia. Later, there was a recurrence of the cyst which was watched for a number of years before consent for an operation was obtained. At operation, performed in September 1946, the cyst was cleaned out and the cavity was packed with cancellous bone chips from the bone bank.

Fig. 1-A (August 28, 1946) shows the condition before operation.

Fig. 1-B (November 26, 1949) shows the appearance two years later.

Fig. 1-C (April 12, 1950): The medullary cavity has been fully reestablished.

period of three years and comprises 202 operations on 160 patients. In addition, I have included results from the Veterans Hospital, Kingsbridge Road, New York City, where a bone bank has been in operation since September 15, 1947. The technique followed there is similar to that used at the Hospital for Special Surgery. This gives an additional seventy-six operations on fifty-four patients, or a total of 278 operations on 214 patients. The data concerning this clinical material are listed in Table I.

Method of Bone Preservation

We have continued to use the same technique for the preservation of bone as is described in my earlier paper. These bone donations are taken from any operative procedure in which healthy, uninfected bone is excised, — especially amputated limbs or ribs removed during the course of operations on the thorax. The amount of bone obtained from wedge osteotomies or arthrodeses on the feet is small in most instances but is large in the aggregate, and the bone is thus worth saving. In addition, we frequently find it possible to remove portions of the iliac crest in adults, when this region is exposed during an operation upon the hip, since this facilitates closure of the wound without tension. When amputations are to be performed in "clean" cases, a special surgical team is alerted to go to work on the amputated extremity and to prepare the bone for storage. This work is laborious, but it presents an excellent opportunity for the resident doctors to perfect their technique in the use of motor-driven, cutting instruments. They are inspired by the

TABLE I

PATIENTS, OPERATIONS, AND WOUND HEALING

(April 1946 to March 9, 1949)

	Hospital for Special Surgery	Veterans Administration Hospital	Total	Per cent. of Operations
Patients	160	54	214	
Operations	202	76	278	
Bone donors	197	84	281	
Wound complications:				
Wounds healed without loss of bone	4	0	4	1.4
Wounds in which sinus still persists	1	1	2	0.7
Wounds in which there was loss of bone	2	0	2	0.7
Total with wound drainage	7	1	8	2.8
Average period of refrigeration	69 days	29 days		
Longest period of refrigeration	649 days	150 days		

knowledge that as a result of their efforts the bone bank will be enriched. Thus, if the surgeons of any hospital are vigilant and cooperative, they will find many opportunities of obtaining bone for the bank. By this means we have been able to keep abreast of our demands at the Hospital for Special Surgery, although at times by a narrow margin. We have not yet been able to make use of bones from cadavera since this is generally prohibited by the difficulty of surmounting the legal restrictions within the short period of time when such bone should be obtained.

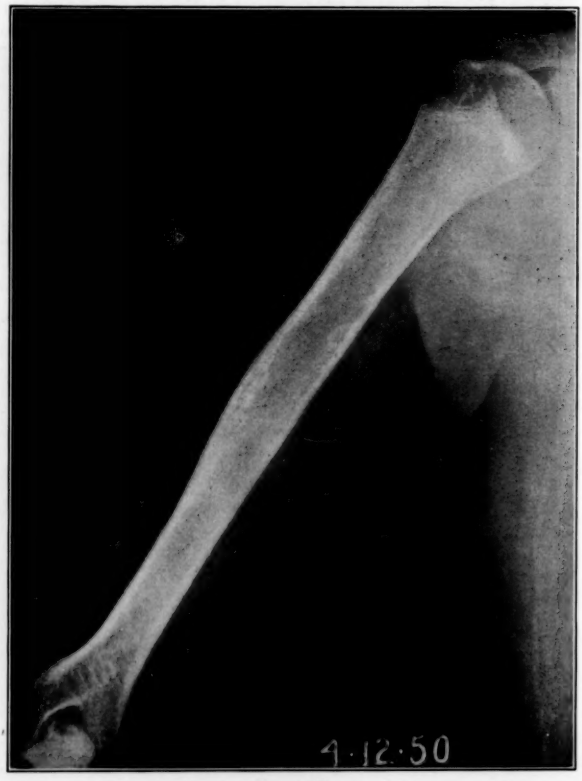


FIG. 1-C

As for the preparation of the bone, it should be cleaned of all soft tissue and cartilage, which is much easier to do when it is in the fresh state. Cortical bone is cut into strips from one-half inch to three-quarters inch wide and from four inches to eight inches long; the marrow and endosteal tissues are left undisturbed. Cancellous bone is generally preserved in whatever size the fragments are obtained originally.

The bone may be cultured by rubbing sterile cotton swabs over its surface. We have found that this method yields a high contamination rate, because of the difficulty of

sterilizing cotton to a degree where all spores are killed and also because of the facility with which the cotton may pick up air-borne contamination. Formerly, we used this method, but more recently, on the advice of Dr. K. Magill of the Boston City Hospital, we have employed the method of cutting away a small fragment of the bone and dropping it in a sterile-broth medium.

The bone is then placed in a sterile jar. We generally make use of the regular five-inch and ten-inch flat-topped glass jars, with screw caps, that are made for the refrigeration of foods. If the piece of bone is too large for these jars, as is frequently the case with ribs, we employ a glass jar of the sort used for pathological specimens. After the cap has been screwed in place, the cap and the upper part of the jar are covered with a piece of sterile rubber sheeting which is held in place by a rubber band. This seals the jar and allows its humidity to be retained, while at the same time the sterility of the upper part near the cap is preserved. It is important to distribute several bone specimens among different jars in order to avoid the danger of contaminating the remainder when only a small piece of bone is taken from the jar. As soon as the jar is sealed, it is placed in a refrigerator where the temperature is maintained at a level of between minus 10 and minus 20 degrees centigrade.

As far as the refrigerator is concerned, the author believes any of the standard commercial models, which are capable of maintaining the desired temperatures, may be used.

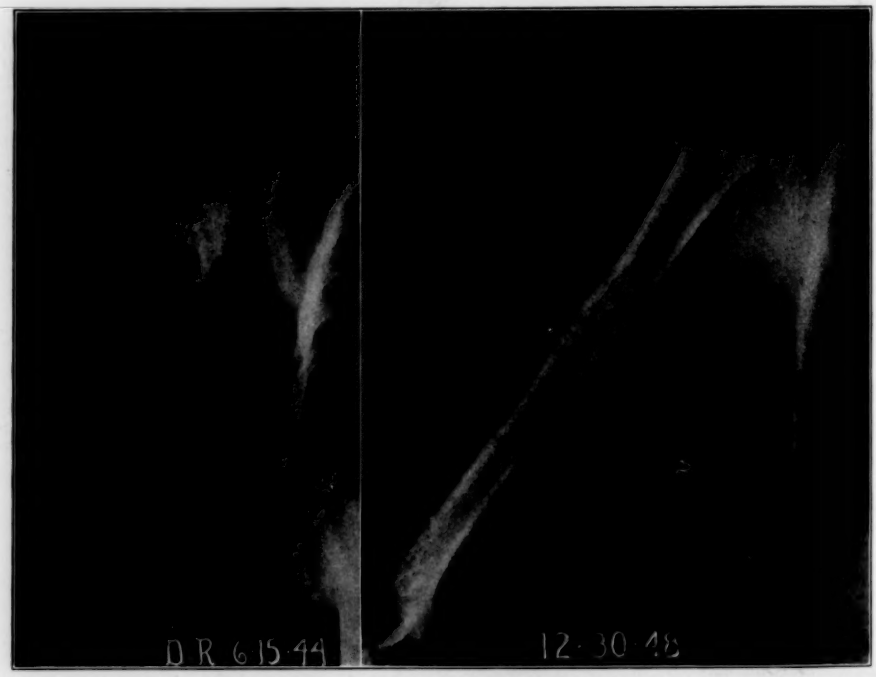


FIG. 2-A FIG. 2-B

The patient, first seen in 1942, at the age of six years, had cystic disease of the humerus with a fracture through the cyst. When he was operated upon, the cavity was curetted and filled with autogenous bone chips. The cyst recurred and he was again operated upon June 15, 1944. The cyst was then cleaned out and cauterized with carbolic acid. However, the cyst recurred within six months, but no further treatment was carried out until October 30, 1947, when he was re-admitted to the Hospital because the cyst was enlarging. The cyst was again operated upon and the contents cleaned out through a large opening. The cavity was filled with cancellous bone chips from the bone bank. One year later, a roentgenogram revealed complete healing.

Fig. 2-A: The roentgenographic appearance in 1944, three years before operation.

Fig. 2-B: The appearance thirteen months after operation.

TABLE II

END-RESULT STUDY OF 144 PATIENTS (179 OPERATIONS)

	No. of Patients	No. of Operations	No. of Successful Operations	Insufficient Time for Follow-up	Failure of Operation	Failure of Operation (*Per cent.*)
Spine fusions for:						
Scoliosis	37	66	57	6	3	4.5
Tuberculosis	8	12	7	2	3	25.0
Low-back pain	33	33	27	3	3	9.0
Cervical lesions	2	2	2	0	0	0.0
Miscellaneous conditions	2	2	2	0	0	0.0
Total spine fusions	82	115	95	11	9	8.4
Filling of bone cavities (benign)	24	26	19	1	6	23.0
Osteomyelitis	9	9	7	1	1	11.0
Joint arthrodesis	12	12	7	2	3	25.0
Ununited fractures	14	14	13	0	1	7.0
Miscellaneous	3	3	3	0	0	0.0
Total	144	179	144	15	20	11.0

We were fortunate to obtain a custom-built model one year ago with a wide-opening front door, fitted with shelves which allow for a more orderly arrangement of the stored bone than was possible with our former top-opening model. It has the disadvantage that its temperature rises quickly when the door is opened, but this makes little difference if one is careful to keep this period to the minimum. Our refrigerator is fitted with a recording thermometer which provides a record of the fluctuations of temperature over a period of one week.

TABLE III

AN ANALYSIS OF RESULTS IN SPINE FUSIONS

Indications	No. of Patients	No. of Operations	Result of Operation				Vertebral Spaces				
			Successes	Failures (*No.*)	Failures (*Per cent.*)	Insufficient Time for Follow-up	No. Fused	No. of Successes	Failures (*No.*)	Failures (*Per cent.*)	Insufficient Time for Follow-up
Scoliosis											
Poliomyelitis	16	36	32	2	5	2	189	175	7	3.7	7
Idiopathic	14	16	12	0	0	4	103	84	0	0.0	19
Congenital	2	4	4	0	0	0	19	19	0	0.0	0
Spina bifida	2	5	4	1	20	0	18	15	3	16.0	0
Round back and Morquio's disease	3	5	5	0	0	0	29	29	0	0.0	0
Total for scoliosis	37	66	57	3	4.5	6	358	322	10	2.7	26
Tuberculosis	8	12	7	3	25	2	51	39	12	23.0	0
Low-back pain (the fourth and fifth lumbar and sacrum)	33	33	27	3	9	3	67	52	10	13.0	5
Cervical lesion	2	2	2	0	0	0	6	6	0	0.0	0
Miscellaneous	2	2	2	0	0	0	4	4	0	0.0	0
Total	82	115	95	9	8.4	11	486	423	32	6.6	41

FIG. 3-A

FIG. 3-B

FIG. 3-C

The patient, a child of two years, had osteitis fibrosa cystica of the humerus and was operated upon September 8, 1947. The cavity was curetted and packed with bone chips from the bone bank.

Fig. 3-A shows the original condition. The child returned in November 1949 with a small recurrence in the middle of the shaft of the humerus (Figs. 3-B and 3-C), which was again operated upon by the same method.

The freshly obtained bone is stored on a special "hold" shelf until a bacteriological report of the specimen is obtained from the laboratory, releasing it for use. Then it is moved to shelves designated for cancellous or cortical bone available for use. In the laboratory, the bone is cultured in broth media under aerobic and anaerobic conditions for a period of four days. If at the end of this time there is no growth, it is reported sterile. When evidence of bacterial contamination of the specimen is reported from the laboratory the question of whether this is the result of air-borne contamination or whether the specimen itself is infected must be answered. For this purpose, the jar is reopened in the laboratory under sterile conditions, the bone is extracted, and fresh swabbings are made for reculture. By this means, we have been able to salvage a number of specimens which were at first reported to be contaminated. When a specimen has been proved to be contaminated, it should be discarded. Bacteriologists are in agreement that many strains of bacteria, including the common pathogens, are resistant to freezing and may survive and grow after being exposed to temperatures as low as 50 or 60 degrees below zero for weeks or months.

Other precautions followed with bone donors include a serological test for syphilis and a questioning of the patient to rule out any history of malaria or of recent acute infectious diseases including infectious hepatitis. Each jar is labelled as to its contents. Further, careful records are kept of every piece of bone, showing the name of the donor, the donor site, the date when it was obtained, the date when it was used, the name of the patient, and the result as far as wound healing is concerned.

TABLE IV

AN ANALYSIS OF RESULTS OF FILLING BONE CAVITIES

	No. of Patients	No. of Operations	No. of Successes	No. of Failures
Cavities caused by:				
Osteitis fibrosa cystica	10	11	8	3
Fibroma of bone	1	1	1	
Osteoid osteoma	3	3	3	
Hemangioma	2	2	2	
Enchondroma	3	3	2	1
Fibrous dysplasia	3	3	1	2
Giant-cell tumor	1	1	1	
Screw holes (congenital pseudarthrosis)	1	1	1	
Total	24	25	19	6

Our records show that the average period of refrigeration for all the bone specimens used at the Hospital for Special Surgery was sixty-nine days, and for those at the Veterans Hospital, twenty-nine days. Several specimens were used after preservation for more than one year, while the longest period of preservation of a specimen used was 649 days or 1.7 years. The results from the use of such an antique specimen seemed to be as good as when the bone is used after a very short period of storage.

Complications of Wound Healing

As shown in Table I, wounds healed by first intention in all but eight of the 278 operative procedures. In these eight cases there was drainage, but four healed spontaneously after varying periods without effect upon the final result. Two of the wounds were still draining through small sinus when last seen, but in two cases there was a definite infection of the wound and it was necessary to re-operate and to clean out the bone graft in order to obtain healing. One of the latter patients was "clean", but the other had chronic osteomyelitis with sinus formation at the time of operation and was, therefore, infected from the first. This gives an infection rate of 1.4 per cent. which compares favorably with the figure of from 1 to 2 per cent. frequently stated to be the average experience with infections in "clean" orthopaedic operations

FIG. 3-D FIG. 3-E

Roentgenograms, August 16, 1950, show complete healing of the lesion.

FIG. 4-A

FIG. 4-B

Figs. 4-A and 4-B: The patient, a man of forty-two years, had a benign cystic lesion of the proximal end of the ulna which had been proved by biopsy. He was operated upon in January 1948 and the lesion was curetted and packed with bone chips from the bone bank.

Fig. 4-A: September 26, 1947. The appearance of the lesion before operation.

Fig. 4-B: January 10, 1949. Complete healing had been obtained.

FIG. 5-A FIG. 5-B FIG. 5-C FIG. 5-D

The patient, a man aged thirty-seven years, was admitted to the Hospital in April 1948, with an ununited fracture of the right radius of four months' duration. He was operated upon April 22, 1948. The fragments were realigned and fixed with a Kuntschner nail. A rib from the bone bank, three inches long, was split into four fragments, which were placed about the fracture site, and were held by closure of the soft tissues. The distal end of the ulna was also resected.

Figs. 5-A and 5-B (April 21, 1946), show the fracture at the time of admission.

Figs. 5-C and 5-D, made nearly one year after operation (March 16, 1949), show that the grafts have healed, forming a large amount of callus. The nail was removed later, and the result is excellent.

We reviewed the records of the patients for evidence of general or local reactions, other than infection, which might be attributed to the implantation of the homogenous bone, but found only one. This patient had a high, sustained fever, following operation, which persisted for more than two weeks without adequate explanation. It then subsided, but there was never any evidence of reaction about the wound. There were two instances of what may have been infectious hepatitis and one of estivo-autumnal malaria; but, as all of these patients received blood transfusions, it seemed logical to consider that, if there was any transmission of an infectious agent, it was through the blood rather than the bone.

FIG. 6

The patient had residual paralysis of the hand after poliomyelitis. It was necessary to stabilize the thumb with reference to the index finger. This was accomplished by placing a graft from the bone bank between the first and second metacarpals. The roentgenogram shows the complete healing of the graft one year later.

On the basis of this evidence, I think it may be definitely stated that with a careful technique it is possible to obtain and to preserve bone for use in operations by refrigeration without any greater danger than if fresh, autogenous grafts are used. The evidence also indicates that human tissues tolerate these preserved homogenous bone grafts without reaction even when the bone has been preserved for a period of more than one year. The incidence of wound complications was no greater than if autogenous grafts had been used. It did not seem necessary to take into account the blood grouping or the Rh factor.

BONE HEALING

In order to determine how well the refrigerated bone fulfilled the desired purpose of serving as a substitute for autogenous bone, we made a follow-up study of all patients in whom homogenous bone grafts were used at the Hospital for Special Surgery, eliminating only those in whom the postoperative period was too short to permit an evaluation of bone healing. Generally, the minimal period for bone healing to be determined was six months, but there were exceptional cases in which clear evidence of healing was noted in a shorter period; such cases were included. The bone bank at the Veterans Hospital has been operating for a shorter period of time than that at the Hospital for Special Surgery; therefore, it was not considered desirable to make a follow-up study of the patients at the Veterans Hospital at this time. It was possible to follow 144 patients who had undergone 179 operations.

A list of the operative procedures and an analysis of the results obtained are shown in Table II. There were twenty operative failures found or 11 per cent., but four of the failures were due to surgical error and, thus, the figure should be reduced to sixteen or 8.8 per cent.

Spine Fusions

It may be noted from Table II that more than one-half of the operations were spine fusions, but there was a wide variety of conditions for which these operations were performed. The author thinks that, in general, regardless of what operative technique is employed, it is difficult to secure a solid fusion of any desired area of the spine, and the chances of failure increase with the number of vertebrae included in the area of fusion. Our own opinion, which is probably shared by many orthopaedic surgeons, is that the secret of a successful fusion lies in having an abundance of bone available for grafting, in addition to whatever autogenous bone may be obtained in the area of operation. Since the availability of the bank bone answers the requirement of an abundance of bone fully, it is only natural that it should be utilized extensively for this purpose. In addition, spine

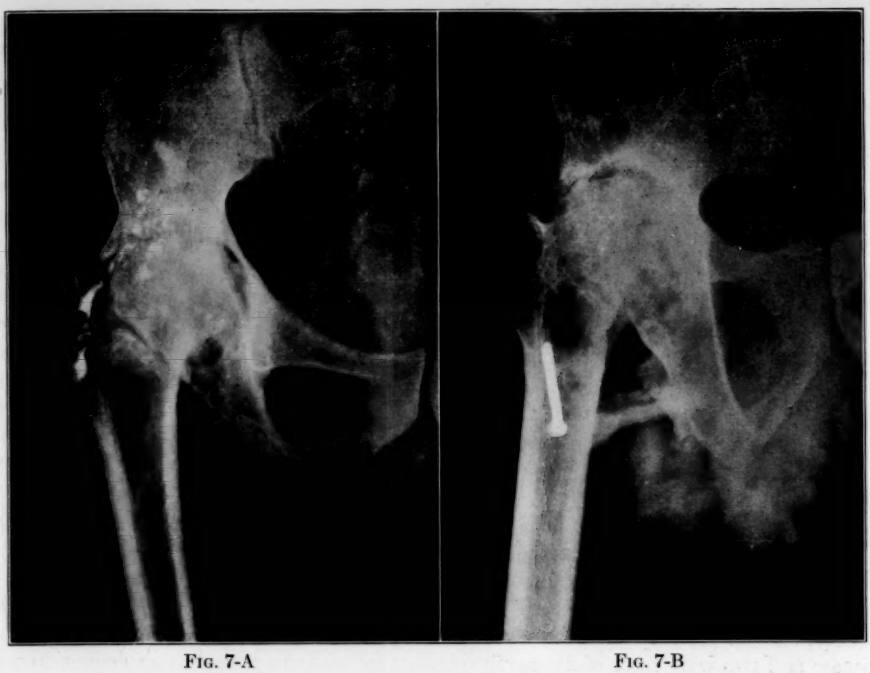


FIG. 7-A FIG. 7-B

The patient, a man aged thirty-nine years, had tuberculous arthritis of the hip. The hip was fused by the Trumbull procedure, using a tibial cortical graft from the bone bank.

Fig. 7-A (June 8, 1949) shows the condition before operation.

Fig. 7-B (October 30, 1950) shows the result one year after operation. The graft has become revascularized and is solidly healed; the hip is beginning to fuse.

fusion is a serious operation in which the surgeon is eager to avail himself of any short cut to avoid the necessity of a secondary operation upon the patient, which may add to hemorrhage and shock.

In Table III, the author has presented an analysis of the various conditions resulting in scoliosis for which spine fusion was performed and also an analysis of such pathological lesions as necessitated spine fusion. It will be seen that the highest failure rate in this group was found in those patients who had had spine fusions performed for spina bifida and tuberculous spondylitis. While the number of patients who were treated for these conditions is too small to make the figures significant, it is well recognized by orthopaedic surgeons that there are good reasons to explain the high incidence of failure in these patients. We think we have reason to be proud of the low rate of failure in the operations for scoliosis, which amounted in the aggregate to 4.5 per cent. This is largely accounted for by the fact that these operations were performed by one surgeon who has had a large experience in this field of work. It also proves that refrigerated, homogenous bone serves as well as autogenous bone, when good technique is used in the operations.

The results of fusion of the fourth and fifth lumbar vertebrae to the sacrum for low-back pain have been subjected to criticism in recent years, since when the patients were examined roentgenographically, with the spine in flexion and extension, the results have shown a high percentage of failures. All of the cases listed in this category were examined in this manner, and the results were evaluated according to the written opinions of our roentgenologist, Dr. Raymond Lewis, who is noted for his fearless reporting of findings. On this basis, our record of three failures, or 9 per cent., in thirty-three operations in which reliance for supplemental bone was placed entirely on refrigerated bone, surpasses

reports by other surgeons where autogenous bone grafts were used. Looking at the total of nine failures in 115 operations for spine fusion, we think we have reason to claim that the results from the use of refrigerated, homogenous bone grafts are as good as any results from the use of autogenous grafts which have been published.

Filling of Bone Cavities

In Table IV are shown the results obtained from the treatment of twenty-four benign lesions, chiefly involving the long bones. It will be seen that this category includes a variety of different lesions, of which osteitis fibrosa cystica is the most common, with osteoid osteoma, fibrous dysplasia, and enchondroma the next most common, in that order. The eradication and cure of these lesions necessitates the removal of all tumor tissue and the filling of the cavity with osteogenic material in order to obtain an obliteration of the defect. Many of the cavities are large; therefore, it is often difficult to obtain sufficient autogenous bone to fill them completely. Even with the best technique, recurrences are not uncommon; and, in our experience with the use of autogenous grafts, it has been necessary in some instances to re-operate more than once in order to obtain final complete healing.

Our experience with the use of refrigerated, homogenous bone for the operative treatment of these lesions has been highly successful. The healing and blending of the transplanted bone with the bone of the host has been, in many cases, quite rapid. Its outstanding advantage is that the abundance of bone available allows lavish use. This is quite the opposite of the situation when autogenous bone is used, especially in children. In the present series, there were six failures, of which three were cases of cystic disease and two were cases of fibrous dysplasia. One case, diagnosed as an enchondroma, and treated accordingly, turned out to be a chondrosarcoma. This case is listed as a failure, although this listing is quite unrelated to the healing properties of the transplanted bone. On the whole, the author considers the results obtained in this group of patients to be wholly comparable with the results obtained when autogenous bone is used.

Osteomyelitis

There were nine patients with chronic osteomyelitis, with bone cavities which could not be obliterated by osteoplastic methods. After thorough débridement, the defects were filled with small, refrigerated bone chips, and the wounds were closed. All but one of these wounds healed by first intention; seven of these cases were considered completely successful after periods of one year or more, and one is too recent for evaluation. One case was a failure; there was a persistent sinus and, after a year, a secondary operation was performed in which the bone was removed.

All of these patients had low-grade infections and sinus at the time of operation, and it seems to us that successful results in seven out of the eight cases which were followed may be considered highly satisfactory. These results prove that refrigerated, homogenous bone is well tolerated by human tissues; otherwise, there would have been more failures.

Joint Arthrodesis

Refrigerated homogenous grafts were used in twelve arthrodeses, as shown in Table V, with three failures. In two cases, the time was too short following operation to evaluate the results. The first of the failures was in a case of active tuberculous arthritis of the hip, where the grafts were absorbed; the second was in a patient with paralytic instability of the knee, for whom a knee fusion had previously been performed, the result of which had been delayed union. A large, refrigerated, homogenous graft was driven across the joint, but a sinus developed, which is still draining, and the fusion is not solid. A third case is listed as a failure, since the patient died ten days after operation of abdominal

TABLE V

AN ANALYSIS OF RESULTS OF JOINT FUSIONS

Indications	No. of Patients	No. of Operations	No. of Successes	No. of Failures	Insufficient Time for Follow-up
Tuberculosis					
Knee	2	2	1		1
Hip	1	1		1	
Non-infectious lesions					
Wrist	5	5	4		1
Knee	1	1		1	
Hip	2	2	1	1	
Foot	1	1	1		
Total	12	12	7	3	2

complications. Wound healing was complete, and the result is in no way attributable to the use of bank bone.

Ununited Fractures

There were fourteen cases of ununited fractures which were repaired with the aid of refrigerated, homogenous grafts. The distribution of these fractures and the results obtained are shown in Table VI. For the most part, the ends of the fragments were freshened, approximated, and fixed by some form of internal fixation. Then onlay grafts or barrel-stave grafts of split ribs were used. There were fifteen operative procedures with two failures. One of these was in a patient with an ununited fracture of the navicular where a peg graft of cancellous bone was inserted, which was later absorbed. The second failure was in a patient who had sustained a band-saw injury of the back of the hand with loss of the distal portions of the metacarpals and of the extensor tendons of all four fingers. Two operations were performed. The first was an excision of the entire second ray and a transplantation of the excised proximal phalanx to replace the end of the third metacarpal. This resulted successfully, and a year later a second operation was performed to replace the distal ends of the fourth and fifth metacarpals and to stabilize these meta-

TABLE VI

AN ANALYSIS OF RESULTS IN UNUNITED FRACTURES

Site of Fracture	No. of Patients	No. of Operations	No. of Successes	No. of Failures
Humerus	2	2	2	
Radius	1	1	1	
Ulna	1	1	1	
Carpal scaphoid	1	1		1
Femoral neck	2	2	2	
Intertrochanteric area	1	1	1	
Femoral shaft	2	2	2	
Tibia	1	1	1	
Fibula	1	1	1	
Medial malleolus	1	1	1	
Metacarpals	1	2	1	1
Total	14	15	13	2

carpophalangeal joints by fusion. Phalanges from the bone bank were hollowed out and used as tubular bone grafts. These were fitted over the ends of the metacarpals, and the bases of the phalanges were tapered and inserted into the distal ends of the metacarpals. The result was successful in the fourth metacarpal, but pseudarthrosis developed at the metacarpal end of the graft in the fifth ray. While this is reported as a failure, the function of the hand was greatly improved, and the patient is satisfied with the result.

Miscellaneous Operations

There were three operations of a miscellaneous nature, including two shelf operations on hips, and one bone block between the bases of the first and second metacarpals to obtain stability of the thumb. In these cases the grafts had only small contact with the host bone, but all showed definite evidence of having become revascularized and incorporated into the hosts' skeletal structure. The results were considered successful.

DISCUSSION

The author has analyzed the results obtained from the use of homogenous bone with the purpose of showing whether or not refrigerated homogenous grafts served as well as autogenous bone grafts in operations upon the bones and joints. We think that the study shows that they are well tolerated and do not cause any adverse tissue reaction when they are free from infection. They heal satisfactorily and become incorporated in the host's skeleton. Whether this transformation is as rapid as with autogenous grafts is difficult to determine. In some of the patients where large, cortical grafts were used, we gained the impression that the healing was slower than would have been the case had autogenous grafts been used. This simply meant that it was necessary to protect the parts by splinting for longer periods of time.

In my previous paper I presented a comparative study of the healing of autogenous bone chips and of homogenous bone chips which had been recovered after different periods of time during second-stage and third-stage operations for scoliosis. These tissues were studied by Dr. Milton Helpern, Pathologist at the Hospital for Special Surgery, who stated that, as far as he could see, the process of healing was similar and comparable in all instances. We thought that in both the graft died and was then revascularized by the host and that the bone underwent a process of absorption and replacement until it finally had been converted into living bone. How many of the living cells of an autogenous graft survive when it is transplanted to another region of the body is problematical; however, it is extremely doubtful that a large enough number of these cells retain enough vitality to make any substantial difference in the healing of the graft. In the author's opinion, the fate of both types of grafts is the same. Their function is threefold: (1) They have a catalytic function in that their presence promotes and influences the osteogenic reaction; (2) they serve as a framework or scaffolding to guide the invading elements of the host; (3) they serve as a local supply of calcium. If these conclusions are correct, then the survival of a few cells more or less in the graft makes no great difference, except possibly from the standpoint of time.

Another question that is not yet answered is whether or not life remains in any of the elements in the refrigerated grafts. Several unquestioned instances of cells retaining life after long exposures to subzero temperatures have been reported to me by colleagues who are engaged in experimental physiological and pathological studies. Carrel was able to demonstrate the growth of the periosteum and an osteogenic reaction after the tissue had been exposed to low temperatures for some time. On this basis, the possibility that some cells may survive cannot be ruled out. We would not expect such cells, even if alive when transplanted, to play any important part in the healing of the graft. It seems to us that their fate would be the same as those in a homologous skin graft where the immediate result appears to be healing, but loss of the graft follows.

In view of the fact that grafts of non-vital bone may consolidate and play an important role in the healing of fractures, and in the filling of bone defects, and in the fusion of joints, one may ask whether sterile, refrigerated animal bone might not serve as well as human bone? The author believes that, since tissue specifically plays a part in healing, such a graft would not be well tolerated unless all cellular elements were previously removed, in which case it would be comparable to the os purum of Orell. We know from Gallie's and Orell's studies that both boiled beef bone and os purum can be used successfully in the human skeleton; but the number of failures, particularly with the former, is high and, in my opinion, does not compare with the results achieved in this series with the use of homogenous bone.

The advantages of a bone bank in a hospital where there is an active orthopaedic service are multiple. The first and most important is sparing the patient the necessity of a secondary operation elsewhere on the body to obtain bone (such bone is generally obtained from the ilium or tibia). It is well known that operative defects in the latter bone are frequently painful for long periods and that they often weaken the bone to such an extent that fracture may occur. In addition, such operations prolong the procedure and add to the hemorrhage and shock. The second advantage is the constant availability of bone for transplantation whenever needed, and it sometimes happens that the need is not foreseen until the operation is well under way. In connection with this point, it should be added that bank bone is available in such abundance that there is no need to be niggardly in its use; this may make a considerable difference when it comes to packing a bone cavity with bone chips. The third advantage is that the surgeon may select from the stock in the bone bank the exact type of bone that is suited to his operation. This offers a much wider choice than would be the case otherwise,—for example, phalanges and metacarpals may be available for transplantation into the hand (we may even come to the time when whole joints or parts of joints may be preserved for transplantation). This is exemplified by the case of ununited fractures of the metacarpals reported earlier in this paper.

As a final word, I might add that the members of the Orthopaedic Staff at the Hospital for Special Surgery have come to depend upon the bone bank to such an extent that autogenous grafts are rarely used, and yet the number of operations in which grafts are employed has increased. In other words, when bone grafts can be had without the necessity of removing them from the patient's skeleton, more ways will be found of employing them during the course of operations upon the bones, and to the patient's advantage.

Problems in the Operation of a Bone Bank

There are still unsolved problems in connection with the operating of a bone bank. One of these is how to guard against the danger of transmitting the virus of infectious hepatitis or the parasite of malaria. As previously stated, we have had no instance of such complications in any of our patients; but the recent occurrence of several cases of jaundice and one of malaria following blood transfusion emphasizes the fact that the danger exists. The method used by Reynolds and Oliver of preserving the bone in merthiolate solution would presumably eliminate this danger, but it remains to be proved whether bone that is preserved in a chemical solution will serve as well in the host, as bone that is not so treated, notwithstanding the good results listed in the preliminary report of these authors.

Another and recurring problem is whether it is safe to use bone that is not involved in the disease from an extremity that is amputated for a malignant bone tumor. We have used bone from the tibia in an extremity that was amputated for liposarcoma of the femur without any complication, but a medical-legal question of considerable importance is raised here, for which it is difficult to obtain any authoritative answer. We are told by

colleagues who are experimenting with tumors in animals that it has been possible to transplant tumors only in mice who are especially bred for that purpose and who show a genetic sensitivity to the tumor.

Similarly there is the problem of whether it is safe to use what appear to be healthy ribs which are obtained from a thoracoplasty for pulmonary tuberculosis.

These and other problems can be answered only by animal experimentation. In the meantime we will have to wait and use our best judgment in settling these matters for ourselves.

SUMMARY AND CONCLUSIONS

In a study of 214 patients who were subjected to 278 operations in which sterile homogenous bone grafts were used, wound infection occurred in four cases (1.4 per cent.) and there was loss of the grafts in two (0.7 per cent.).

In a follow-up study to determine the final results with respect to healing of the refrigerated homogenous bone grafts, 144 patients were traced who had undergone 179 orthopaedic operations for a large variety of conditions. Considered on a basis of the number of operations, the results were found to be successful in 80 per cent. and unsuccessful in 11 per cent. Fifteen patients (9 per cent.) had undergone operations too recently for a determination of the results. By eliminating four cases in which the failure was unrelated to bone healing, the rate of failure can be lowered to 8 per cent.

This study justified the following conclusions:

1. With careful technique, homogenous bone grafts may be preserved for long periods of time for surgical use.

2. Such grafts are well tolerated by human tissues and the risk of infection is no greater than with autogenous grafts.

3. The healing of such grafts takes place by a process of invasion, absorption, and replacement similar to that of autogenous bone grafts.

4. The results obtained are identical with those from the use of autogenous grafts, except that in some instances the healing appears to be a little slower.

5. The operation of a bone bank is safe and practical. It offers great advantages to the patient and the surgeon from the standpoint of availability, abundance, and the elimination of the necessity of a secondary operation to obtain bone.

REFERENCES

1. Bush, L. F.: The Use of Homogenous Bone Grafts. A Preliminary Report on the Bone Bank. J. Bone and Joint Surg., **29:** 620–628, July 1947.
2. Carrel, Alexis: Preservation of Tissues and Its Application to Surgery. J. Am. Med. Assn., **59:** 523–526, 1912.
3. Gallie, W. E.: The Transplantation of Bone. British Med. J., **2:** 840–844, 1931.
4. Henry, M. O.: Homografts in Orthopaedic Surgery. J. Bone and Joint Surg., **30-A:** 70–76, Jan. 1948.
5. Orell, Svante: Use of Os Purum in Implantations. Surg., Gynec., and Obstet., **66:** 23–36, 1938.
6. Reynolds, F. C., and Oliver, D. R.: A Clinical Evaluation of the Merthiolate Bone Bank. J. Bone and Joint Surg., **32-A:** 283–296, Apr. 1950.
7. Weaver, J. B.: Experiences in the Use of Homogenous (Bone Bank) Bone. J. Bone and Joint Surg., **31-A:** 778–792, Oct. 1949.
8. Wilson, P. D.: Experiences with a Bone Bank. Ann. Surg., **126:** 932–946, 1947.

DISCUSSION

Dr. J. S. Speed, Memphis, Tennessee: We are indebted to Dr. Wilson for this presentation of the conclusions that he and his colleagues have reached from a careful analysis of a large series of cases in which refrigerated, homogenous bone has been used as a substitute for fresh, autogenous grafts.

Although a large amount of clinical and experimental data concerning this subject has been accumulated in recent years, we must still regard the use of refrigerated bone as a source of graft material in the experimental or formative stage. In the final analysis, the value of this procedure can be determined only by the results of its clinical application to reconstruction problems in the human being. Laboratory studies and animal experimentation are helpful but not conclusive.

The reports of Bush, Wilson, Reynolds and Oliver, Weaver, and others have done much to clarify the uncertainties connected with the use of refrigerated bone and apparently justify the conclusion that there is very little difference theoretically or clinically in the "take" of fresh or refrigerated grafts. The splendid results which Dr. Wilson has reported further confirm such a conclusion. The results which we have had in a similar series of over one hundred cases are so nearly parallel to those obtained by Dr. Wilson that I believe our series could be incorporated into Dr. Wilson's statistical analysis without changing the result percentages. Such uniformity of results in two entirely independent series should encourage the use of this procedure in the treatment of major reconstructive problems. It is in such problems that we most frequently encounter the need for large amounts of graft material, which for various reasons may not be available from the patient. The use of fresh homogenous bone is an excellent solution of the search for graft material so far as the recipient is concerned, but there are many obvious reasons why it is not a comparable experience for the donor. There is still considerable doubt as to just how massive a piece of refrigerated bone can be satisfactorily revascularized and hence successfully transplanted.

Bone grafts consist essentially of three elements: the mineral element, the collagen element, and the cellular element. The mineral and collagen element are probably preserved in their original form by refrigeration; practically all the cellular elements die, just as they do in fresh grafts. There may be in fresh bone some enzymes aiding in callus production, which are destroyed by refrigeration. Observation of bone that has been refrigerated for prolonged periods of time indicates that a slow process of protein autolysis may alter the collagen element. Chip grafts, either fresh or refrigerated, react in essentially the same manner.

We have been particularly interested in the behavior of the large refrigerated grafts of the size ordinarily used for the massive onlay type of graft. We have been able to follow twenty-four of these cases for a long enough period of time to form a comparison with the results of our use of fresh autogenous grafts.

In non-unions we have used the single onlay, refrigerated homogenous graft in fifteen cases with three failures and the dual onlay grafts in nine cases with two failures. There was no obvious difference clinically or roentgenographically in the "take" of these grafts as compared with the fresh autogenous. The percentage of failure was higher in the refrigerated grafts, but this might easily be accounted for by the type of case in which they were used.

Perhaps the best method for comparison was that used in five dual bone grafts, where in each case one graft was a fresh autogenous and the other a refrigerated homogenous graft. No essential difference was noted in the "take" of the grafts and, where the density of both grafts was the same at the time of application, they were usually indistinguishable in the roentgenogram. Both types eventually became incorporated into the host bone.

In spite of all of the favorable evidence which we have accumulated regarding the efficacy of refrigerated grafts, the inconsistency of human judgment is proved by the fact that, in the difficult case where a fresh autogenous graft is available, I still prefer to use it.

DR. ALAN DEFOREST SMITH, NEW YORK, N. Y.: I have asked for this brief time simply to tell, in general, of our results at the New York Orthopaedic Hospital which have paralleled in time those of Dr. Wilson's at the Hospital for Special Surgery.

Our experience has been that we have had a higher percentage of failures in our spine fusions with the bank bone grafts than with the autogenous. Garber and Bush, at our hospital, did a series of experiments on rabbits, in which they demonstrated that the "take" of a graft was best in the case of a fresh autogenous, next in a fresh homogenous, next in a frozen autogenous, and fourth in a frozen homogenous graft; so we prefer, when possible, to use fresh autogenous bone. We think the results are better. Nevertheless, we do get good results with the frozen, homogenous bone, and it is a great help to be able to fall back upon it; but I think that we should not regard it as being quite as satisfactory as fresh, autogenous bone. We should use the fresh autogenous bone whenever we can.

The bank is very useful in preserving grafts for spine fusions which are to be done in stages,—as in scoliosis where a good tibial graft is taken at the first operation and a portion of it is preserved to be used in the next procedure.

DR. WILSON (closing): I was very pleased with Dr. Speed's discussion. He has had a lot of experience with the use of refrigerated bone and, certainly, his experience does parallel our own. Reports from around the country, where a great deal of interest seems to be shown at the present time in bone banks, seem to be in general very encouraging. We know that Dr. Smith and his colleagures are not quite so well impressed with the results as we are, but we think that the experiments on small animals are not conclusive. The practical test of final results in patients seems to me to be more important, and we have presented our results for you to see. It seems to me that they are as good as we could expect if we had used autogenous bone.

EFFECT ON BONE GRAFTS OF RADIO-ACTIVE ISOTOPES OF PHOSPHORUS *

BY RICHARD T. ODELL, M.D., C. BARBER MUELLER, M.D., AND J. ALBERT KEY, M.D., ST. LOUIS, MISSOURI

From the Department of Surgery, Washington University School of Medicine, St. Louis

The purpose of this investigation is to determine the variations in the uptake of radio-active phosphorus (P^{32}) by autogenous bone and various types of preserved bone both when utilized as inlay grafts and when placed intramuscularly.

Neuman and Riley have shown that, following injection of radio-active phosphorus into animals, as much as 5 per cent. of the injected radio-active substance will be found in the skeleton in twelve to twenty-four hours [1]. Falkenheim, Neuman, and Hodge found by *in vitro* studies that finely ground particles of cortical bone, when stirred in a solution of radio-active phosphorus, adsorbed 30 per cent. of the isotopes in the first eight hours and 50 per cent by the end of 240 hours. This uptake of phosphorus was described as an interchange of ions of phosphorus between the solution and the solid bone particles in which nearly one-fifth of the phosphorus atoms in the solid bone might ultimately take part. "The adsorption presumably occurs on the surfaces of the ultra microscopic crystals of hydroxyapatite; measurements of specific surface area show that large adsorbing surfaces are present" (100 square meters per gram of bone). This indicates a large active inner surface.

TABLE I

AVERAGE AMOUNT OF PHOSPHORUS (PER GRAM OF BONE IN ADULT DOGS) IN BONE AND CALLUS

Bone	Age of Graft			
	1 Week	2 Weeks	3 Weeks	4 Weeks
Autogenous graft	0.106	0.107	0.113	0.105
Boiled graft	0.106	0.107	0.115	0.106
Frozen graft	0.118	0.105	0.105	0.101
Callus	0.024	0.054	0.063	0.072
Normal bone = 0.108		Error = ±0.0062		

Kiehn and his associates, employing radio-active phosphorus as a tracer substance, have measured the uptake of P^{32} by free grafts placed in the subcutaneous tissue of dogs. They used iliac grafts of autogenous bone, some of which had been boiled and some preserved by freezing. The intact ilium on the opposite side of the animal was used as the control. Having noted a greater uptake of phosphorus by frozen autogenous bone than by boiled autogenous bone, they concluded that frozen autogenous bone remained viable. They have shown that frozen grafts gain increasing amounts of radio-active phosphorus after longer periods in the host animal, while boiled bone acquires as much radio-activity as the frozen graft in the initial two days after injection but does not gain or lose any radio-activity in the subsequent six weeks. These workers did not explain why the boiled bone acquired radio-activity in the initial two days following injection.

Tucker attempted to study aseptic necrosis of the femoral head by its uptake of P^{32} at the time of operative reduction of a fracture of the femoral neck, and concluded that a

* Read at the Annual Meeting of The American Orthopaedic Association, Virginia Beach, Virginia, May 25, 1950.

devascularized femoral head became only 10 per cent. as radio-active as normal bone within one hour after the intravenous injection of radio-active phosphorus. This is apparently a problem of the spread of phosphorus into the substance of the femoral head, and is undoubtedly an excellent method of determining whether or not the head still has blood supply. Tucker presupposed that, in the absence of blood supply, the free femoral head would undergo aseptic necrosis.

Feeling that the uptake of radio-activity by bone tissue when surrounded by a physiological medium is a matter of ion interchange and a function of the surface presented to the medium containing radio-activity, the authors have studied differences in the uptake of radio-active phosphorus by autogenous, boiled, and frozen grafts. It was originally hoped that these studies might elucidate the problem of the viability of certain types of bone grafts.

A. *Comparison of the Uptake of P^{32} by Autogenous, Boiled, and Frozen Bone when Used as an Inlay Graft.*

Seven normal adult mongrel dogs were used. Under nembutal anaesthesia with sterile technique, the left tibia was exposed and the periosteum was stripped from the superior medial aspect. With an oscillating Luck bone saw, three grafts, each measuring 0.7 by 1.0 centimeter in size, were taken; this left a peninsula of normal bone, 1 centimeter in width, between the grafts. The superior graft was freed and then restored to its bed. The middle graft was placed in boiling water for ten minutes and then returned to its bed. The inferior graft was discarded and replaced with an accurately shaped piece of frozen bone. This bone had been removed from the tibia of another dog and preserved at −20 degrees centigrade for two to four weeks prior to its use. The graft beds were cut with beveled edges and all grafts were inlaid so that the outer surface was level with that of the tibia. All grafts were fitted to within 0.3 millimeter and none was forced into place under pressure. Careful closure of the periosteum was accomplished with interrupted 00 plain catgut. Interrupted fine silk was used to close the fascia and skin. Two weeks later this procedure was repeated upon the right hind leg.

TABLE II

VARIATIONS IN COUNTS PER MINUTE PER MILLIGRAM OF PHOSPHORUS FROM VARIOUS AREAS OF CORTICAL BONE IN THE TIBIAE AND FEMORA OF A NORMAL DOG *

Femora	Tibiae
223	166
228	288
199	223
288	233
240	251
251	184
230	220
233	234

* Four weeks after injection of 4 millicuries of P^{32}

The dogs were sacrificed either one or two weeks after the second procedure. This permitted one animal to furnish grafts either one and three weeks old or two and four weeks old. Three days prior to sacrifice, each animal received approximately 4 millicuries of radio-active phosphorus as a subcutaneous injection of disodium phosphate *. The operative site was exposed and each graft was removed carefully. All visible callus was removed from the graft and a portion of each graft, weighing approximately 100 milligrams was placed in a tared 25-milliliter flask and weighed immediately. Samples of callus and normal bone were also removed for analysis. The bone was wet-ashed with 1.5 milliliters of concentrated nitric acid for at least three days, and diluted to 25 milliliters by volume. From this, aliquots were taken for determination of the phosphorus and radio-activity.

* The authors are indebted to Dr. Edward Reinhard of the Department of Hematology for a generous supply of radio-active phosphorus.

TABLE III

COUNTS PER MINUTE PER MILLIGRAM OF PHOSPHORUS IN NORMAL BONE AND IN GRAFTS AND CALLUS *

Time Interval (*Weeks*)	Dog No.	Normal Bone	Autogenous Graft	Autogenous Boiled Graft	Homogenous Frozen Graft	Callus
1	1	34	20	15	13	674
	2	10	12	9	5	624
2	3	21	26	25	18	1,265
	4	55	65	8	12	760
	5	1,900	714	366	369	22,100
3	1	32	226	83	98	674
	2	38	187	56	40	935
4	3	11	129	56	69	915
	4	76	79	39	—	377
	5	572	1,415	1,060	547	6,840

* All samples taken three days after subcutaneous injection of 4 millicuries of P^{32}.

Phosphorus was determined by the Fiske-Subbarow method and radio-activity was measured with a Geiger-Mueller counter and a decimal scaler. Determination of the amount of phosphorus in the bone and in the graft was made, for we consider it more accurate to report the amount of P^{32} per milligram of phosphorus than per gram of bone.

Examination of the graft sites at the end of one week showed a slight amount of callus formation, chiefly endosteal. All grafts looked pale and were easily lifted from their beds. At each succeeding week, the amount of callus increased steadily, so that at four weeks each of the grafts was almost completely covered with a heavy callus layer that fixed them in place, but did not seem to arise from or incorporate these grafts into its own substance. The frozen and boiled grafts at four weeks looked pale; the autogenous grafts were a faint pink, of the same color as normal bone, and the line between graft and shaft was almost obliterated.

Analyses of the bone grafts for total phosphorus (P^{31} and P^{32}) showed a constant amount of phosphorus per gram of wet bone in the three types of grafts and in normal bone. Twenty-nine pieces of normal cortical bone from tibiae and femora were analyzed for phosphorus; the average content was found to be 0.108 gram of phosphorus per gram of bone. There was no significant difference from this figure for any of the bone grafts regardless of conditions of the graft or duration in place in the animal. The total amount of P^{32} is much less than 1 per cent. of the total amount of phosphorus in the bone or in the graft.

Analyses of portions of callus showed that the phosphorus content of callus was relatively low at the end of one week (0.024 gram of phosphorus per gram of bone); this progressively increased so that, at four weeks, callus contained 0.072 gram of phosphorus per gram of bone, about 70 per cent. as much phosphorus as does normal bone (Table I).

Analyses of the bone grafts for radio-activity showed that, in each leg, the autogenous graft took up more P^{32} than either boiled or frozen grafts. In the analyses of normal bone from tibial shafts, a variation in the counts per minute per milligram of phosphorus of as much as 175 per cent. was encountered (Table II). For this reason, the counts per minute per milligram of phosphorus in the autogenous graft were used as the base to which the counts in the boiled and frozen grafts were compared. This was represented as 100 per

cent. for each leg; the counts in the boiled and frozen grafts are reported as percentage of counts per minute per milligram of phosphorus in the autogenous grafts. These data are presented in Chart I and Table III for determinations made at one, two, three, and four weeks after implantation of the graft. P^{32} concentration is reported as counts per minute per milligram of phosphorus. Radio-activity in the callus at one to four weeks of age averaged fifty-seven times that of normal bone. We are not able to explain the unusually high counts in animal No. 5. It is possible that this animal received an unduly large dose of P^{32} by mistake.

B. *Comparison of Release of P^{32} by Homogenous and Boiled Bone when Used as an Inlay Graft*

A dog was injected with 4 millicuries of radio-active phosphorus and four weeks later homogenous radio-active grafts were transplanted from this dog into the tibiae of four normal mongrel dogs. Each tibia received a normal homogenous graft and a boiled homogenous graft. The grafts were taken from the femora and tibiae of the donor dog; additional small pieces of bone adjacent to each graft were removed for determination of phosphorus and radio-activity, as described in Section A. In the small pieces of bone adjacent to the donor graft sites, the amount of radio-activity varied considerably from one area of bone to another (Table III). These were used as controls to determine the original content of P^{32} for each graft.

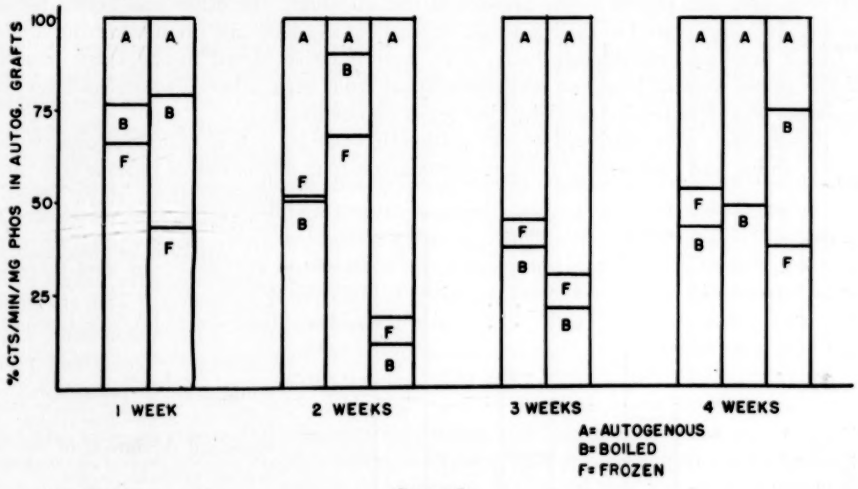


CHART I

Comparison of the amount of P^{32} in autogenous bone, boiled bone, and frozen bone, when used as an inlay graft. In each instance, the amount of P^{32} in the autogenous graft is plotted as 100, and the amount in the boiled and frozen grafts in the same leg is plotted as a percentage of this.

The counts were so low in the radio-active grafts after transplantation and elapse of time allotted for healing that the error in determination of the radio-activity was greater than the change in counts per minute due to loss of P^{32} from the graft. Consequently, these results are not presented in detail.

C. *Comparison of the Uptake of P^{32} by Autogenous, Boiled, Frozen, and Merthiolate Bank Bone when Placed in the Muscles of the Thigh*

Two adult mongrel dogs were used. By the technique described in Section A, two autogenous grafts, each weighing approximately 100 milligrams, were taken from the

TABLE IV

COUNTS PER MINUTE PER MILLIGRAM OF PHOSPHORUS AND PHOSPHORUS CONTENT OF GRAFTS IMPLANTED IN THE MUSCLES OF THE THIGH *

	Autogenous Graft	Autogenous Boiled Graft	Homogenous Frozen Graft	Merthiolate Graft
2 weeks				
Grams of phosphorus per gram of bone	0.100	0.102	0.098	0.106
Counts per minute per milligram of phosphorus	132	62	75	16
3 weeks				
Grams of phosphorus per gram of bone	0.101	0.104	0.099	0.100
Counts per minute per milligram of phosphorus	415	197	434	94
4 weeks				
Grams of phosphorus per gram of bone	0.102	0.102	0.095	0.103
Counts per minute per milligram of phosphorus	173	64	104	22

* All samples taken three days after subcutaneous injection of 4 millicuries of P^{32}.

left tibia. One was placed in the muscles of the left thigh; the other was boiled for ten minutes and then placed in the left thigh. Sections of the same size, removed from a piece of frozen bone and merthiolate bank bone, were likewise placed in the thigh muscles. All the pieces were at least one centimeter apart from each other. Two weeks later, the procedure was repeated in the right hind leg of one of the dogs.

The animals were sacrificed at such a time that one leg was obtained for observation at two, three, and four weeks. Each dog was given four millicuries of radio-active phosphorus, three days prior to sacrifice.

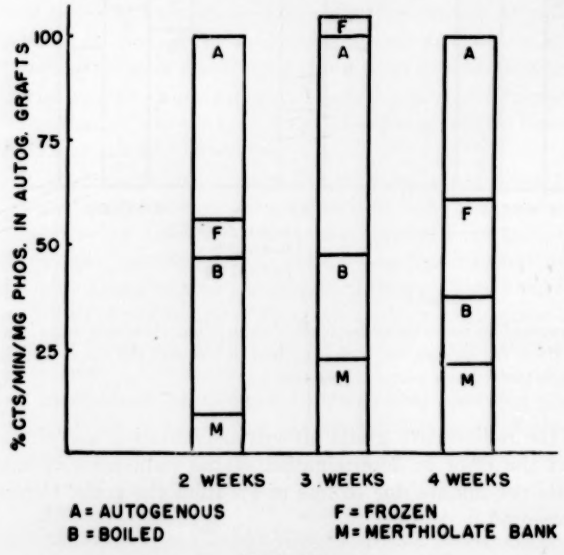


CHART II

Comparison of the amount of P^{32} in autogenous, boiled, frozen, and merthiolate bone when placed in the muscles of the thigh. In each instance, the amount of P^{32} in the autogenous graft is plotted as 100, and the amount in the other bones is plotted as a percentage of this.

Analysis of this bone for phosphorus gave values within normal limits, with the exception of the frozen bone, which consistently contained about 0.003 gram of phosphorus per gram of bone less than the standard deviation of our accepted normal values.

Analysis of these bone fragments for radio-activity showed that the autogenous bone at all times contained roughly five times as much P^{32} as the merthiolate bone and twice as much as the frozen bone and boiled bone.

One exception was that, at three weeks, the autogenous bone and frozen bone contained the same amount of radio-active phosphorus (Table IV and Chart II).

DISCUSSION

Kiehn and his associates and Tucker have developed the thesis that the uptake of P^{32} by bone or cartilage is a measure of the viability of a free graft. Falkenheim, Neuman, and Hodge have shown that the incorporation of P^{32} into finely ground bone during a period of equilibration with a solution containing P^{32} is a factor of ion exchange between the solution and the phosphorus in the bone crystal. In physiological media, the accumulation of radio-activity by the bone is accomplished by the withdrawal of P^{32} from the solution, but there is no actual increase of the amount of phosphorus in the bone, because as the P^{32} is adsorbed, an equal amount of P^{31} is set free in the solution. Thus the amounts of total phosphorus (P^{31} and P^{32}) in the bone and in the surrounding medium remain practically unchanged, although the ratio of P^{31} to P^{32} in each may vary from time to time.

The acquisition of P^{32} by the bone or bone grafts is a function of the surface exposed to the solution perfusing the graft or bone, whether it be the external surface or through the tiny canals. Since the outer surface area of a piece of bone is relatively minute as compared to that presented to solutions perfusing the Haversian system, the availability of these canals to the surrounding plasma or lymph is probably the factor which largely determines the quantity of P^{32} eventually taken up. This may well be a function of viability, but it may also be a property of the relative porosity of bone. In any case, it cannot be asserted dogmatically that a greater uptake of P^{32} by one piece of bone over another indicates that one is more viable.

We have often found that our grafts, even the boiled ones, contained more radio-activity than the normal bone shaft which is known to be living. In Section C it has been shown that boiled bone takes up about twice as much P^{32} as a comparable amount of merthiolate bone.

If it is true that the ability to take up P^{32} is evidence of viability of the graft, this would indicate that boiled bone is more viable than merthiolate bone. In this laboratory, Reynolds and Oliver have shown that grafts of merthiolate bone are united to the surrounding bone by appositional new growth, and are replaced by living bone more quickly and with more certainty than are similar grafts of boiled bone. It is thus evident that the ability of bone grafts to take up P^{32} from the surrounding medium and to become radio-active not only is not a sign of viability of the bone, but is not even a reliable indication of the value of this bone when used as a graft.

In evaluating the results of the experiments described, the authors have seen that autogenous bone grafts consistently become more radio-active than other forms of grafts, all of which had been subjected to either physical or chemical alteration during preservation. This includes anoxia, low temperature, boiling, and immersion in solutions containing mercury. It is well known that all of these physical and chemical agents are capable of producing profound alterations in protein structure. It must be that alteration or denaturation of the protein matrix of these grafts denies access of the perfusing solution to some of the regions of the grafts. This hypothesis could readily explain all of our findings without demanding that we assume that the uptake of P^{32} is an indication of living or dead bone.

In the experiments described in Section B, an attempt was made to determine the release of P^{32} from bone grafts which had become radio-active following a prior injection of P^{32} into the donor dog. In all cases, after correcting for the 14.6 day half-life, we were unable to demonstrate any significant decrease in the quantity of P^{32} in the bone graft during its period in the host. It is probable that, after a four-week interval in the donor dog, the P^{32} was incorporated in the deeper interstices of the bone as well as on any surfaces which might be expected to undergo ion exchange during a briefer period of equilibration, such as was used in the experiment described in Sections A and C. Were this so, the loss of P^{32} from the surfaces might be such a relatively small fraction of the total contained in the graft that our counting methods would be unable to detect the loss.

An analysis of all grafts showed a constant proportion of the bone to be phosphorus. In the handling of a free graft by the host animal, it is presumed that the graft becomes incorporated into the bone structure by creeping replacement. Our observations support this theory. If the graft were originally dissolved by removal of either the organic fraction or the calcium-phosphate inorganic portion of the bone, without concomitant removal of the other fraction, the ratio of phosphorus to bone would be altered.

The authors' finding that aging callus contains increasing amounts of phosphorus is in agreement with the concept that the callus is initially a fibrous matrix, capable of producing a local increase in calcium or phosphate ions and subsequent precipitation of the bone salt. Using autoroentgenograms, Bloom, Curtis, and McLean demonstrated the rapid uptake of P^{32} by the fast-growing epiphyseal bone. The new bone formed by callus acts in a similar manner and takes up P^{31} and P^{32} indiscriminately. Consequently some P^{32} is adsorbed by the bone in the callus, and some is used in the formation of new bone. The result is that the callus contains considerably more P^{32} than does normal bone or any of the grafts (when freed from callus) (Table III).

SUMMARY

Fourteen dogs were used to measure the relative rates of phosphorus-ion exchange from autogenous, boiled, frozen, and merthiolate bank bone. Comparing the rate of uptake of P^{32} by boiled and frozen inlay grafts in the tibia to that of autogenous inlay grafts at one, two, three, and four weeks, three days after subcutaneous injection of radio-active phosphorus, the authors have shown that autogenous bone becomes more radio-active than the other varieties. The same has been found true for autogenous, boiled, frozen, and merthiolate bone when placed intramuscularly for two, three, and four weeks.

We do not believe that this is evidence of the viability of autogenous bone as compared to types of preserved bone. Neither do we feel that this is proof that all free grafts are dead. It corroborates the clinical impression that autogenous bone best serves the purpose of a free graft. We feel that the increased uptake of P^{32} by autogenous over other types of free grafts indicates that the recesses of these grafts are more easily reached by the perfusing solutions, due perhaps to the lesser alteration of the protein matrix.

CONCLUSIONS

1. Analyses of autogenous, boiled, and frozen grafts show no significant alteration in the content of total inorganic phosphorus in bone with time or condition of the graft.

2. The uptake of radio-active phosphorus by inlay autogenous bone grafts is more rapid than the uptake by similar grafts of boiled or frozen bone.

3. The uptake of radio-active phosphorus by intramuscular autogenous bone chips is more rapid than the uptake by frozen or boiled bone. Merthiolate bone consistently takes up less radio-activity than boiled or frozen bone.

REFERENCES

1. Bloom, William; Curtis, H. J.; and McLean, F. C.: The Deposition of C^{14} in Bone. Science, **105**: 45, 1947.
2. Falkenheim, Marlene; Neuman, W. F.; and Hodge, H. C.: Phosphate Exchange as the Mechanism for Adsorption of the Radioactive Isotope by the Calcified Tissues. J. Biol. Chem., **169**: 713–722, 1947.
3. Kiehn, C. L.; Triedell, H. L.; Beason, Jerrel; Berg, Marvin; and Glover, Donald: A Study of the Viability of Autogenous Frozen Bone Grafts by Means of Radioactive Phosphorus. Personal communication, 1950.
4. Kiehn, C. L.; Friedell, H. L.; and MacIntyre, W. J.: Study of the Vitality of Tissue Transplants by Means of Radioactive Phosphorus: Preliminary Report. Plastic and Reconstruc. Surg., **3**: 335–339, 1948.
5. Nageotte, P.: Les greffes osseuses. Paris, Masson et C^{ie}, 1920.
6. Neuman, W. F., and Riley, R. F.: The Uptake of Radioactive Phosphorus by the Calcified Tissues of Normal and Choline-Deficient Rats. J. Biol. Chem., **168**: 545–554, 1947.
7. Reynolds, F. C., and Oliver, D. R.: Experimental Evaluation of Homogenous Bone Grafts. J. Bone and Joint Surg., **32-A**: 283–297, Apr. 1950.

8. TUCKER, F. R.: The Use of Radioactive Phosphorus in the Diagnosis of Avascular Necrosis of the Femoral Head. J. Bone and Joint Surg., **32-B**: 100–107, Feb. 1950.

DISCUSSION

DR. C. HOWARD HATCHER, CHICAGO, ILLINOIS: The authors apparently initiated these experiments with the assumption that radio-active phosphorus would be deposited in new living bone formed in and about a graft, and would thus serve as a marker to differentiate the newly formed bone from the old transplanted bone. They found that there is evidently an interchange of the radio-active phosphate ion with the minerals of the skeleton, which interferes with the use of the radio-active substance as a marker. This ionic interchange, which appears to take place on the free surfaces of bone, is very disturbing to our older ideas of the qualitative stability of bone once it has been calcified. Despite the fact that the authors have not discovered just what happens to the elements of free bone transplants, they have obtained valuable information. It is clear from their work that the autogenous graft is more permeable to tissue fluids and to the ingrowth of living cells than is a transplant altered by chemical or physical means. This does not mean that preserved grafts are not effective clinically, but that the early changes in the fresh autogenous transplant are more favorable to its incorporation in the skeleton than is the case with treated transplants.

Accurate and careful interpretation of histological sections is still the best means for determining the fate of the various elements of the bone transplant. Observations indicate that the transplanted bone substance dies and loses its osteophytes; the marrow cells die also. However, undifferentiated connective-tissue cells, which can be reached readily by serum permeating from the host, do survive, proliferate, and take part in the initial incorporation of the graft, and in the early replacement of its dead bone. Transplants, subjected to any treatment which destroys these undifferentiated cells, are at a disadvantage in the early stages of replacement. Likewise, any alteration of the graft which interferes with its permeability by surrounding fluids and cells is a disadvantage in this early repair.

The experiments of Dr. Key, Dr. Odell, and Dr. Mueller, pointed toward an explanation of the role of the various elements of bone transplantation, have entered a field which is probably of even greater importance,—that is, the ionic exchange which may go on within the skeleton. It is hoped that the authors will continue this study as applied to the various aspects of bone physiology.

DR. H. HERMAN YOUNG, ROCHESTER, MINNESOTA: We are indebted to the authors of this paper for their excellent presentation of data concerning the fate of various types of bone transplants. Using the newest tool available for the study of bone metabolism, the authors originally set out to determine whether or not transplanted bone remains viable. At the end of their study they concluded, and I believe rightly, that this method of investigation alone cannot be used to determine the viability of a bone transplant.

An air of mystery seems to surround the use of radio-active isotopes in investigative endeavors. Whether this is because we speak of P^{32} (radio-active phosphorus) or Sr^{89} (radio-active strontium) or C^{14} (radio-active carbon) or whether it is because we speak of radio-activity itself, I do not know. At any rate, this mystery should not exist.

Many—in fact, probably all—of the elements can be made radio-active by bombardment in the cyclotron. By this procedure, the chemical properties of the element remain unchanged, and thus radio-active phosphorus, for instance, behaves chemically in the same manner as does ordinary phosphorus. Consequently, when it is introduced into the living organism, radio-active phosphorus enters into all the phases of phosphorus metabolism. These particles of radio-active phosphorus, however, give off beta rays which enable them to be followed by means of the Geiger counter and roentgenograms. In the doses used in investigations of metabolism, all that is accomplished by imparting radio-activity to a substance is to tie a "red tag" on each particle, which will enable us to follow that substance in its course through the human body.

The authors of this paper administered a given amount of radio-active phosphorus to dogs having various types of bone transplants in their tibiae and studied the phosphorus metabolism of these transplants. The facts they have presented are only a part of a complex problem.

As we all know, the two main portions of bone are, first, the organic matrix, and second, the various mineral constituents. The mineral constituents are in a constant state of interchange and, until *in vivo* studies can be conducted on the organic matrix of bone and the findings can be correlated with the behavior of all of the bone salts, the question of the viability of bone transplants cannot be answered. Until these facts are available, the theory of creeping substitution of Phemister will have to be accepted. The study of the metabolism of the mineral salts alone cannot answer the problem, for it is common knowledge that a bone can lose an enormous quantity of its mineral content and still remain viable. It does just that in osteoporosis. Altered mineral metabolism is likewise observed in living bone as, for example, in rickets. I should like to ask the authors of this paper what results they anticipated finding in their investigation in order to prove whether or not the transplants were viable.

Other investigators have shown that radio-active phosphorus is deposited most heavily in the metaphyseal ends of the diaphysis and less heavily in the epiphyses and shafts. Radio-active carbon, on the other hand, is deposited most heavily in the epiphyses and shafts. Thus radio-active phosphorus is deposited

mainly in the areas of most recent bone formation, while radio-active carbon is deposited most readily in old bone.

In their present study the investigators used dogs with tibiae which I assume were approximately fifteen centimeters in total length. In each case the autogenous transplant was placed uppermost in the tibia, the boiled transplant was placed next and the frozen transplant last; five centimeters in all was utilized for the transplants. Isn't it possible, therefore, that the autogenous transplants were placed in the most favorable position for the absorption of the radio-active isotope. Furthermore, it is possible that the boiled-bone transplant which occupied the central portion in all cases was in an area of more embarrassed circulation than the other two transplants. Assuming that the transplants occupied a third of the total length of each tibia, is it not possible that both the upper and lower transplants were in areas where radio-active phosphorus is more readily deposited than the centrally placed transplant? In order to clarify this matter, I believe that normal specimens of bone used as controls should have been taken from areas of the tibia adjacent to each transplant and the position of the transplants varied. I am told, however, that the specimens removed for controls were taken from the posterior aspects of each tibia without regard for the level of the transplants. Better normal specimens as controls might have helped us to decide whether or not one or the other of the bone transplants might have been placed in a less advantageous position.

I think that the work of Tucker has not been refuted. Tucker's work was with a normal femur which met with an accident to the femoral neck. He tried by studies with radio-active phosphorus to determine the extent of damage to the circulation of the femoral head. Although his series of cases was small, he found that a ratio of 1 to 3 or 3 to 1 of radio-active phosphorus content between the head and trochanter was evidence of a normal circulation to the head fragment. When this ratio changed to 1 to 10 or 1 to 16, aseptic necrosis developed. This observation supported his theory, derived from animal experimentation, that aseptic necrosis was based on impairment of circulation. The present authors, however, started with bone transplants entirely devoid of circulation and originally hoped to show that a blood supply was acquired and that at least the organic matrix of the graft survived.

If further investigation with the use of more accurate controls substantiates the findings of the present investigation, then a real contribution to our knowledge has been made. The facts, so far, would seem to substantiate our present clinical impression that autogenous bone is the best transplant to use when it is available, and that various types of preserved bone, although not so good, are still useful when autogenous transplants cannot be acquired.

I have enjoyed reading this paper and appreciate the opportunity to discuss it. If I have seemed over-critical, it is only with the hope of arousing sufficient interest to lead us to an answer as to what happens to a bone transplant.

DR. J. ALBERT KEY (closing): I am very glad to have these criticisms. Dr. Hatcher is right when he says we started out to prove one thing and found that it did not work. He suggests that it is very simple to look in a microscope and tell living bone from dead bone, but this was not our experience. Cells may remain in dead bone for some time, especially if they had been fixed before the graft was inserted. It is particularly difficult, when using boiled bone or merthiolate-preserved bone, to tell which bone was inserted and which has formed.

Dr. Young has explained about the tagging of phosphorus and other elements with radio-active substance so that they can be followed, as he says, as though they had a red tag on them. Also, it is pretty well established now that the body will use either radio-active or non-radio-active elements, depending upon which form is available.

For a good many years, I have been interested in the relation of connective-tissue cells to the matrix. In 1921, when I was an intern in Boston, Dr. Osgood and I transplanted dead grafts in tendon, following the work of Nageotte. He believed that the intercellular substance of bone, nerves, and tendon was dead. Nageotte fixed these tissues in formalin, alcohol, or other substances, and then used them as transplants. He claimed that the graft was not replaced, but that living cells took the place of the dead cells and the old framework persisted. He felt that a dead graft became revivified and was just as good as a living graft.

In examining these grafts under the microscope, I had a great deal of trouble in determining whether or not I was dealing with living tendon or transplanted dead tendon grafts. I tried staining with hematoxylin before transplanting, but even then I had the same difficulty. I stained the bone with alizarin before transplanting, and I could not see the pink color of the alizarin under the microscope. I had hoped that P^{32} would be the answer.

In reply to Dr. Young's question, had we been able to prove that the P^{32} was taken up by the cells in the autogenous bone and not by the dead bone, I think we would have had evidence that this autogenous graft lives. However, finding that the P^{32} is not taken up by the cells, but that its acquisition is an adsorption phenomenon on the surface, leaves us right where we started. In other words, the method is not good for the purpose for which we tried to use it. Whether or not we shall learn more about the metabolism of bone as a continuation of these studies, I do not know.

We did not try to refute Dr. Tucker's work,—his observations are correct. Our work was done before we heard of Tucker's studies.

BIOPHYSICAL AND PHYSIOLOGICAL INVESTIGATIONS ON CARTILAGE AND OTHER MESENCHYMAL TISSUES

II. The Ultrastructure of Bovine and Human Nuclei Pulposi *

BY BENGT SYLVÉN, M.D., STEN PAULSON, M.SC., CARL HIRSCH, M.D., AND OLLE SNELLMAN, PH.D., STOCKHOLM AND UPSALA, SWEDEN

Gradually increasing structural changes in the adult lumbar intervertebral discs may lead to disturbed disc function and thus play a role in the genesis of low-back pain [9, 12]. These changes first affect the nucleus pulposus and may be found in patients between twenty and thirty years of age [9, 12]. According to current descriptions [1, 3–8, 13–17, 20, 21] a variety of so-called regressive changes have been noted both in the cells and in the intercellular matrix. In the latter, a considerable decrease in water content [26] and fibrous alterations of the matrix have been found to occur during aging. On the whole, the gross morphology of these changes is well known [3, 6, 8, 14, 17, 21], but the fundamental details essential for biological interpretation are poorly understood [29, 30]. More data are thus required with regard to the chemical composition, ultrastructure, and biophysical properties of the intercellular matrix.

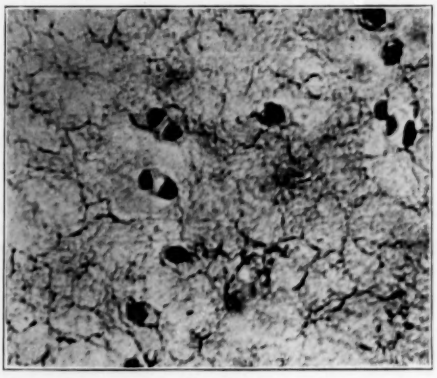


FIG. 1-A

FIG. 1-B

Nucleus pulposus from young calf, showing so-called reticulin fibers stained with Mallory's trichrome.
Fig. 1-A: Fixed in formaldehyde solution. Magnification: 320.
Fig. 1-B: Frozen vacuum-dehydrated specimen. Magnification: 1,500.

This paper embodies (1) a brief account of the histology of the intercellular matrix of normal and degenerated nuclei pulposi as seen in the visual light microscope; (2) a rough estimation of the amounts of metachromatic material present in the nucleus pulposus during different ages; and (3) some electron microscopic data on the ultrastructure of bovine and human nuclei pulposi down to the order of resolution of about 100 to 50 Angström units (1 Angström unit equals 0.1 of a millimicron). The structural details of an order of resolution less than 50 Angström units have been studied by diffusion measurements [24]. More particulars of the composition of the extracted mucoid material and of the characteristics of purified nucleus pulposus collagen, in comparison with other types of collagen, will be presented elsewhere.

* This is the second report of a program of joint investigations on the physiology and nutrition of some mesenchymal tissues under the direction of the *Karolinska Institutet* (Department of Orthopaedic Surgery and the Cancer Research Division of *Radiumhemmet*) and the Institute of Biochemistry at the University of Upsala.

FIG. 2-A

FIG. 2-B

FIG. 2-C

Nucleus pulposus from a man, aged forty-six, without previous history or symptoms of disc lesion. In places, large collagen fiber bundles appear. Mucoid material is still retained in places between the bundles. Formaldehyde fixation; Mallory's trichrome. Magnification: 160.
Fig. 2-A: Nucleus pulposus of second lumbar with moderate degeneration.
Fig. 2-B: Nucleus pulposus of third lumbar presenting more advanced degeneration.
Fig. 2-C: Nucleus pulposus of fourth lumbar with advanced degeneration.

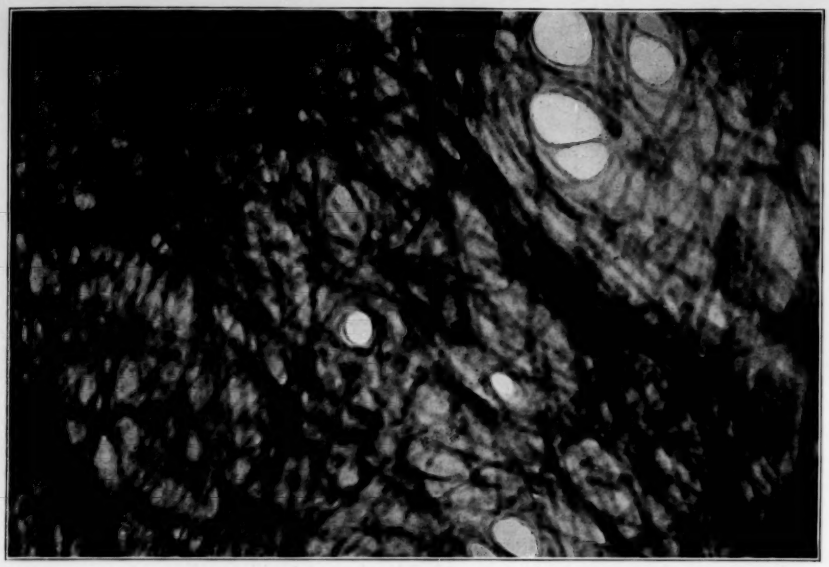


FIG. 3

Electron micrograph of untreated fresh frozen-sectioned nucleus pulposus from a calf, showing the collagen network embedded in an amorphous matrix. Gold-manganine shadowing. Magnification: 23,250 (No. 5048).

1. The Intercellular Matrix

Common connective-tissue stains applied to fresh frozen sections or frozen vacuum-dehydrated sections of healthy nuclei pulposi from calves or young human subjects provide little information. The intercellular matrix envelops everything in an amorphous cloud and only a limited number of small fibers, which have the staining reactions of so-called "reticulin", can be seen (Fig. 1-A). When the same stains are applied to washed or mordanted sections in which some of the matrix has been dissolved or has swollen or both, a moderate number of such "reticulin" fibers are discerned (Fig. 1-B).

These fibers will gradually become more prominent during aging and in areas subjected to "degeneration", and will also gradually assume the typical fuchsinophilia of collagen. The fiber bundles become distinctly thicker and often have a wavy tendon-like course (Fig. 2). Thus they give the impression that, parallel with the partial disappearance of the mucoid matrix, the sparse reticulin fibers, mentioned previously, have been transformed into collagen bundles. It may be inferred that the mucoid may have masked a considerable number of delicate fibers in a similar way to the masking of collagen in cartilage [11].

2. The Amount of Intercellular Metachromatic Material

After freezing and vacuum-dehydration, as well as after mordanting in 5 per cent. formaldehyde solution, all healthy nuclei pulposi from young calves and humans show a uniformly high degree of alcohol-resistant metachromasia throughout the intercellular matrix. The cell cytoplasm stains orthochromatically. The matrix appears more abundant and amorphous in specimens treated by freezing and vacuum-dehydration, but more fibrillar and netlike in mordanted specimens. In some places a concentration of metachromatic material is seen around the chondrocyte-like cell bodies.

The amount of metachromatic material is somewhat diminished in a nucleus pulposus in a state of incipient degeneration, and still further in areas with advanced degeneration in which the metachromatic matrix may be absent.

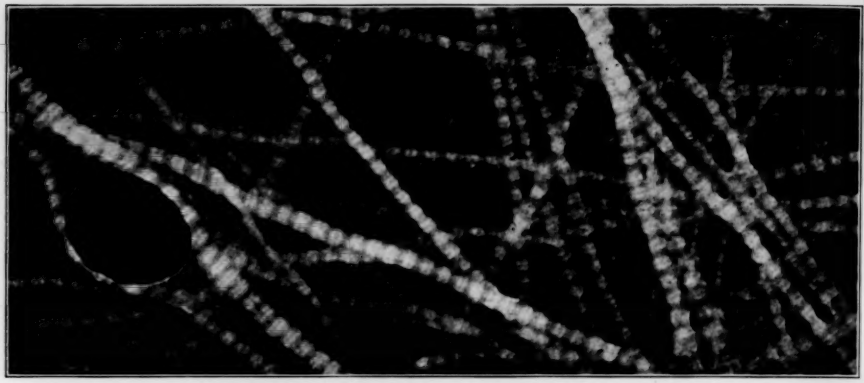


FIG. 4

After partial removal of the mucoid matrix by repeated acetone and water extraction, the fibrils show a typical two-banded collagen periodicity. Staining with phosphotungstic acid, 1 per cent. for 1 minute at pH 7. Magnification: 21,500 (No. 5057).

The degree of alcohol-resistant metachromasia is of the same order of intensity as in cartilage [29]. This suggests that the mucoid material cannot "consist of hyaluronic acid" as stated earlier by Meyer [18], because purified hyaluronic acid has been shown to be non-metachromatic. Unpublished extraction experiments suggest that the polysaccharide material is most probably chondroitin sulphate with an electrophoretic mobility of $u = -10.8 \times 10^{-5}$ square centimeters per volt per second at pH 5.8 and ionic strength of 0.20 (this value should be compared with that of Partridge). Digestion experiments with highly active testis hyaluronidase * were not indicative of the presence of hyaluronic acid [19].

3. The Ultrastructure of the Nucleus Pulposus

In a healthy state, the gelatinous nucleus has a high water content [26] and a low mass. Its dry weight in our specimens from young calves was found to be only 16.5 per cent., which facilitates electron microscopy on fresh frozen sections with a thickness of about three to four micra. The thinnest possible areas of such sections were selected for microscopy. A means of decreasing the mass of the sections further was to make use of the enormous water-binding capacity of fresh specimens, which were allowed to swell for some hours in a damp chamber at + 4 degrees centigrade. When a volume of three to six times the original had been reached, frozen sections were made as mentioned above. This method provided superior results (Fig. 3), but also implies more artefacts in handling the material. The sections were kept in a Dewar bottle until transferred to the electron microscope grids. Washing or other treatment for removal of the interfibrillar material was avoided (Figs. 3, 6, 7-A, and 7-B). Gold manganine was used for shadow casting. A Siemens electron microscope was used.

Nuclei Pulposi from Calves

The tissue was found to contain a dense network of interlacing fibrils with variable diameters, embedded in an amorphous matrix devoid of apparent structure. In fresh unswollen frozen sections, the fiber periodicity was largely obscured, but in swollen sections it was more apparent (Fig. 3). Cell bodies and other thick section areas could not be penetrated by the electron beam. The electron micrographs clearly indicate the very close connection between the fiber structures and the amorphous matrix, as well as the uniform distribution of matrix material throughout the tissue.

* Leo, Inc., Hälsingborg, Sweden.

Experiments were further performed in order to free the fibrils from the surrounding mucoid material by means of repeated acetone and water extractions, followed by differential centrifugation. After such fibrils had been stained in solutions of phosphotungstic acid [PTA] at pH 7, such micrographs as Figures 4 and 5 were obtained. The axial spacing was variable in different fibrils and in sixty measured fibrils [22,28] ranged between 560 and 712 Angström units; the average value being around 635 Angström units, which agrees very well with that of Bear for native collagen (640 Angström units). It was further noted that the fibrils present great variation in width,—from 170 to 1260 Angström units. The mode was about 500 Angström units. No correlation was found between the values of axial spacing and of fibril width.

In general, a two-banded intraperiod structure was obtained [27,28,31]. After being stained with phosphotungstic acid, some fibrils showed a three-banded structure (Fig. 5), which presents some similarity to Porter's pictures on the development of collagen in chick explants [25].

FIG. 5

In this electron micrograph the collagen fibrils show a three-banded intraperiod structure. Same treatment of specimen followed as in Fig. 4. Staining with phosphotungstic acid, 0.3 per cent. for 15 minutes at pH 7. Magnification: 21,500 (No. 5060).

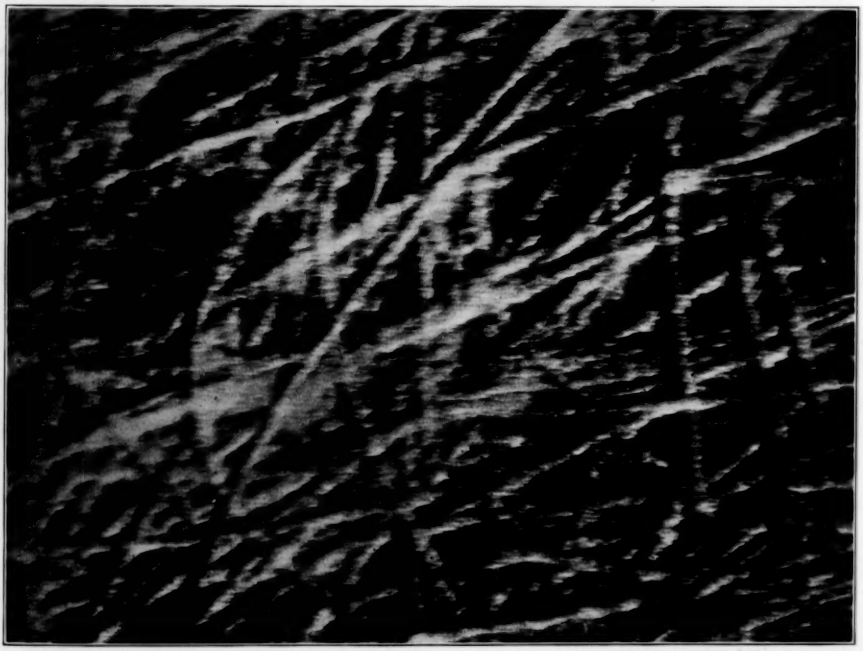


FIG. 6

Electron micrograph of fresh unwashed frozen-sectioned nucleus pulposus from a newborn child. Note the uniform distribution of the mucoid matrix over the fibrils; in places, however, the fibrillar periodicity can be discerned. Gold-manganine shadowing. Magnification: 43,000.

Nuclei Pulposi from Human Subjects

The electron micrograph from a fresh frozen-sectioned lumbar nucleus pulposus of a newborn infant showed a uniform picture of fibrils embedded in an amorphous matrix (Fig. 6), quite comparable to that previously described in calves. Another fresh frozen section from a woman of sixty-six years is shown in Figures 7-A and 7-B. In this specimen, which was in a state of moderate "degeneration", an irregular loss of the amorphous matrix was noted; the collagenous fibrils appeared in places completely or partly unmasked, and here and there matrix remnants were adherent to the fibrils. In other areas, clumps of matrix material still obscured the fiber structures.

DISCUSSION

Present findings lead to the conclusion that the healthy "gelatinous" nucleus pulposus represents a three-dimensional lattice gel system. The embedded collagenous fibrils have only been observed to a minor extent with previous methods, partly due to the masking action of the mucoid material against a number of staining reactions, but mainly due to their small size. Since the mucoid material cannot easily be removed by extraction procedures, it seems conceivable that the chemical connection between this material and the fibrils is very close.

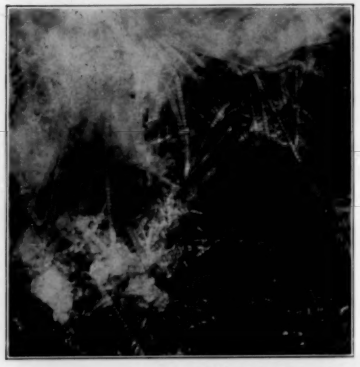


FIG. 7-A

The thin fibers observed in the visual light microscope (Fig. 1) have been denoted as "reticulin", according to common histological terminology. Whether these fibers exist in the native tissue or have been produced by the preparation methods involved [10] cannot be decided. They may, however, represent aggregates of the collagenous fibrils observable in the electron microscope. It should be emphasized that our fresh frozen nucleus pulposus sections have only been dehydrated before shadowing, and have not been subjected to

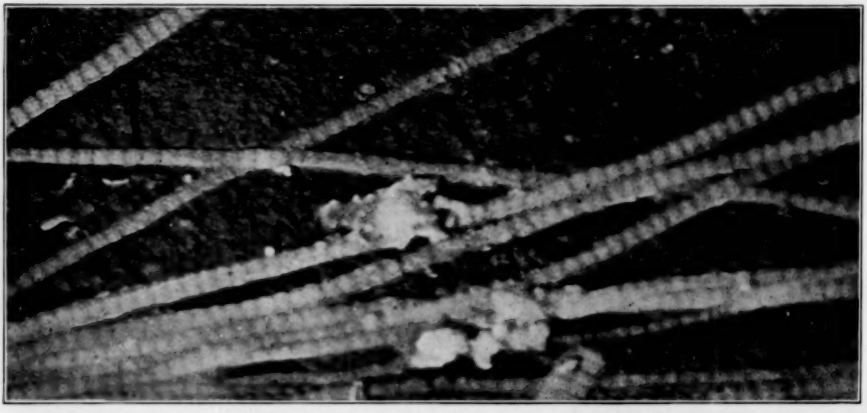


FIG. 7-B

Fig. 7-A: Electron micrograph of fresh unwashed frozen-sectioned nucleus pulposus taken from the first lumbar intervertebral disc of a woman sixty-six years old. The collagenous fibrils are partly unmasked. Gold-manganine shadowing. Magnification: 8,600.

Fig. 7-B: Same case and same treatment as in Fig. 7-A. Electron micrograph taken from the fourth lumbar intervertebral disc. Unwashed fresh frozen section, showing unmasked collagenous fibrils, and clumps of adherent matrix material. Gold-manganine shadowing. Magnification: 43,000.

any washing or other treatment. We believe, therefore, that the observed fibrils are present in the native tissue.

Our electron-microscopic findings agree with the previous statement of Gross as to the typical collagen periodicity of the so-called "reticulin" fibrils.

We hesitate to use the term "degeneration" for the nucleus changes during aging, and we have no means of distinguishing them from the truly pathological changes. It may well be that part of the so-called degeneration is a physiological process, characterized by disappearance of mucoid material and simultaneous differentiation (growth or lateral aggregation) of the fibrils. This will naturally affect the water content and rate of diffusion, whereby there will be a secondary impairment in the nutrition of the avascular gelatinous tissue.

SUMMARY

Electron microscopy of healthy nuclei pulposi indicates that the intercellular matrix should be regarded as a three-dimensional lattice gel system, containing a dense network of poorly differentiated collagenous fibrils and an amorphous interfibrillar substance. During aging, this system becomes subject to an irregular disappearance of the amorphous mucoid material, whereby the fibrils become partly unmasked. The mucoid interfibrillar material is probably responsible for the high water content and water-binding capacity.

REFERENCES

1. Beadle, O. A.: The Intervertebral Discs. Observations on their Normal and Morbid Anatomy in Relation to Certain Spinal Deformities. London, Privy Council Medical Research Council. Spec. Rep. Ser. No. 161: 5–79, 1931.
2. Bear, R. S.: Long X-Ray Diffraction Spacings of Collagen. J. Am. Chem. Soc., **64**: 727, 1942.
3. Bradford, F. K., and Spurling, R. G.: The Intervertebral Disc. With Special Reference to Rupture of the Annulus Fibrosus with Herniation of the Nucleus Pulposus. Springfield, Illinois, Charles C. Thomas, 1947.
4. Böhmig, R., and Prévôt, R.: Vergleichende Untersuchungen zur Pathologie und Röntgenologie der Wirbelsäule. Fortschr. auf d. Geb. d. Röntgenstrahlen, **43**: 541–575, 1931.
5. Coventry, M. B.; Ghormley, R. K.; and Kernohan, J. W.: The Intervertebral Disc: Its Microscopic Anatomy and Pathology. Part I. Anatomy, Development, and Physiology. J. Bone and Joint Surg., **27**: 105–112, Jan. 1945.
6. Coventry, M. B.; Ghormley, R. K.; and Kernohan, J. W.: The Intervertebral Disc: Its Microscopic Anatomy and Pathology. Part II. Changes in the Intervertebral Disc Concomitant with Age J. Bone and Joint Surg., **27**: 233–247, Apr. 1945.
7. Coventry, M. B.; Ghormley, R. K.; and Kernohan, J. W.: The Intervertebral Disc: Its Microscopic Anatomy and Pathology. Part III. Pathological Changes in the Intervertebral Disc. J. Bone and Joint Surg., **27**: 460–474, July 1945.
8. Eckert, Charles, and Decker, Alfred: Pathological Studies of Intervertebral Discs. J. Bone and Joint Surg., **29**: 447–454, July 1947.
9. Friberg, Sten., and Hirsch, Carl: Anatomical and Clinical Studies on Lumbar Disc Degeneration. Acta Orthop. Scandinavica, **19**: 222–242, 1949.
10. Gross, J.: A Study of Certain Connective Tissue Constituents with the Electron Microscope. Ann. New York Acad. Sciences, **52**: 964–970, 1950.
11. Hansen, F. C. C.: Untersuchungen über die Gruppe der Bindesubstanzen. I. Der Hyalinknorpel. Anat. Hefte, **27**: 535–820, 1904–1905.
12. Hirsch, Carl: An Attempt to Diagnose the Level of a Disc Lesion Clinically by Disc Puncture Acta Orthop. Scandinavica, **18**: 132–140, 1948.
13. Inman, V. T., and Saunders, J. B. de C. M.: Anatomicophysiological Aspects of Injuries to the Intervertebral Disc. J. Bone and Joint Surg., **29**: 461–468, July 1947.
14. Joplin, R. J.: The Intervertebral Disc. Embryology, Anatomy, Physiology, and Pathology. Surg., Gynec., and Obstet., **61**: 591–599, 1935.
15. Junghanns, Herbert: Die Zwischenwirbelscheiben im Röntgenbild (Ihre Umbildungen während des Wachstums und ihre krankhaften Veränderungen). Fortschr. auf. d. Geb. d. Röntgenstrahlen, **43**: 275–305, 1931.
16. Junghanns, Herbert: Die Pathologie der Wirbelsäule. *In* Handbuch der speziellen pathologischen Anatomie und Histologie von Henke und Lubarsch, Band 9, Teil 4. Seiten 216–429. Berlin, Julius Springer, 1939.

17. KEYES, D. C., and COMPERE, E. L.: The Normal and Pathological Physiology of the Nucleus Pulposus of the Intervertebral Disc. An Anatomical, Clinical, and Experimental Study. J. Bone and Joint Surg., **14**: 897–938, Oct. 1932.
18. MEYER, K.: Mucopolysaccharides and Mucoids of Ocular Tissues and Their Enzymatic Hydrolysis. *In* Modern Trends in Ophthalmology. Edited by A. Sorsby, pp. 71–78, London, Butterworth and Co., 1948.
19. MEYER, K., and RAPPORT, M. M.: Hydrolysis of Sulfated Mucopolysaccharides by Testicular Hyaluronidase. Fed. Proc., **9**: 205, 1950.
20. MÜLLER, W.: Pathologische Physiologie der Wirbelsäule. Angeborene, konstitutionelle und funktionelle Veränderungen. Kap. 5. Die Bandscheiben. Seiten 108–139. Leipzig, Johann Ambrosius Barth, 1932.
21. NORLÉN, SUNE: Om patologiska förändringar i intervertebraldiskerna. Hygiea, **89**: 159–169, 1927.
22. NUTTING, G. C., and BORASKY, R.: Electron Microscopy of Collagen. J. Am. Leather Chemists' Assn., **43**: 96–110, 1948.
23. PARTRIDGE, S. M.: The Chemistry of Connective Tissue. I. The State of Combination of Chondroitin Sulphate in Cartilage. Biochem. J., **43**: 387–397, 1948.
24. PAULSON, STEN; SYLVÉN, BENGT; HIRSCH, CARL; and SNELLMAN, OLLE: Biophysical and Physiological Investigations on Cartilage and other Mesenchymal Tissues. III. The Diffusion Rate of Various Substances in Normal Bovine Nucleus Pulposus. Biochem. et Biophys. Acta, 1951, in press.
25. PORTER, L.: Personal communication, October 1950.
26. PÜSCHEL, J.: Der Wassergehalt normaler und degenerierter Zwischenwirbelscheiben. Beiträge z. pathologischen Anat. u. z. allgemeinen Path., **84**: 123–130, 1930.
27. SCHMITT, F. O.; HALL, C. E.; and JAKUS, M.A.: Electron Microscope Investigations of the Structure of Collagen. J. Cell and Comp. Physiol., **20**: 11–33, 1942.
28. SCHMITT, F. O., and GROSS, J.: Further Progress in the Electron Microscopy of Collagen. J. Am. Leather Chemists' Assn., **43**: 658–675, 1948.
29. SYLVÉN, BENGT: Cartilage and Chondroitin Sulphate. I. The Physiological Role of Chondroitin Sulphate in Cartilage. J. Bone and Joint Surg., **29**: 745–752, July 1947.
30. SYLVÉN, BENGT: Biological Aspects of the Physiology of Hyaline Cartilage. Acta Orthop. Scandinavica, **18**: 21–27, 1948.
31. WOLPERS, C.: Elektronenmikroskopische Kollagenbefunde. Das Leder, **1**: 3–12, 1950.

VARIATIONS OF STENOSING TENOSYNOVITIS AT THE RADIAL STYLOID PROCESS

BY LYON K. LOOMIS, M.D., NEW ORLEANS, LOUISIANA

From the Department of Orthopaedics, Louisiana State University School of Medicine, New Orleans

Stenosing tenosynovitis at the radial styloid process frequently causes considerable disability in the hand, due to painful thumb motion. Although de Quervain's name has been associated with the disease since 1895, when he reported five cases occurring in women, a good description of the condition is found in the thirteenth edition of Gray's *Anatomy*, published in 1893. At this time, the disease was referred to as "washerwoman's sprain".

ANATOMY

The abductor pollicis longus and the extensor pollicis brevis tendons lie in a groove on the dorsal lateral aspect of the radius. These tendons are covered by (1) synovial mem-

brane, (2) a layer of loose cellular connective tissue, containing fine, thin-walled capillaries and some larger vessels with thin, muscular coats, and (3) a ligament of avascular, dense, fibrous tissue about one thirty-second of an inch thick (the dorsal carpal ligament). The ligament converts the groove into an osseofibrous tunnel, making up the first of six compartments which lie on the dorsum of the wrist.

The abductor pollicis longus arises chiefly from the upper dorsal surface of the radius, from the interosseous membrane, and, to a lesser extent, from the upper ulnar shaft. The extensor pollicis brevis arises from the interosseous membrane and the radius distal to the origin of the abductor pollicis longus.

The insertion of the abductor pollicis longus varies greatly. From a study of 127 dissected forearms, it was found that in only 10.2 per cent. of the specimens was the abductor pollicis longus inserted upon the radial side of the base of the first metacarpal, and there only [7]. In the remaining 89.8 per cent. of the specimens, the abductor pollicis longus had a dual insertion. In order of frequency, the insertions were:

1. Into the abductor pollicis brevis, 59 per cent.;
2. Into the trapezium, 58 per cent.;
3. Into the opponens pollicis, 15.7 per cent.;
4. Into the first phalanx of the thumb, 7.1 per cent.;
5. Into the carpal metacarpal joint, 2.3 per cent.

Of the sixty-four arms dissected by Wagenseil, the same finding was confirmed, — namely, that the abductor pollicis longus usually has two or more tendons of insertion. A dual insertion occurred in 69 per cent. of his cases. The author's own investigation of 100 dissected forearms bears out the fact that a dual insertion of the abductor pollicis longus is usual.

The extensor pollicis brevis also varies greatly in its insertion, as shown by Parsons and Robinson who, after dissecting 118 forearms found insertion into the first phalanx in 72 per cent.; into both phalanges in 21.2 per cent.; and into the terminal phalanx in 6.8 per cent.

In addition to the variation of insertion of both the abductor pollicis longus and the extensor pollicis brevis tendons, a third tendon is sometimes found in, or in close proximity to, the osseofibrous canal of the first compartment. If it is in the canal, it frequently has a separate osseofibrous tunnel, at least, through part of the larger compartment. On the other hand, it may lie entirely outside the first compartment, close to its dorsal side. The incidence of this finding is so much greater as an operative finding than in cadaver dissection that perhaps it should be considered a pathological condition.

In regard to the functions of the two muscles, it is always remembered that the abductor pollicis longus and the extensor pollicis brevis are motors for the thumb, but it is frequently forgotten that the same muscles are the chief radial deviators of the wrist.

INCIDENCE

Age: Although the disease occasionally occurs in the young and the aged, it is most common in the third and fourth decades. A similar disease affecting the flexor pollicis longus in infants is sometimes seen, but that appears to be of congenital origin.

Sex: It is generally accepted that the disease is more common in women than in men. It has been suggested by Bunnell that the increased incidence in women is due to their ability to ulna-deviate the wrist more than men, thereby putting more stretch upon the tendon sheath.

Race: Race seemed not to be a factor.

Body type: The disease is more common in the short, stocky type of individual.

Occupation: People who engage in occupations where the thumbs are fixed when the wrists are ulna-deviated are particularly subject to the disease. It is commonly seen in washerwomen, waitresses, obstetricians, pianists, typists, and carpenters.

FIG. 1

The abductor pollicis longus and extensor pollicis brevis occupy separate osseofibrous canals.

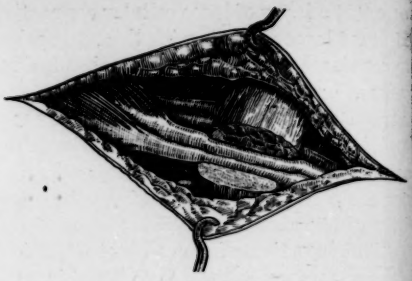


FIG. 2

Stenosis of the two tendons in one osseofibrous canal.

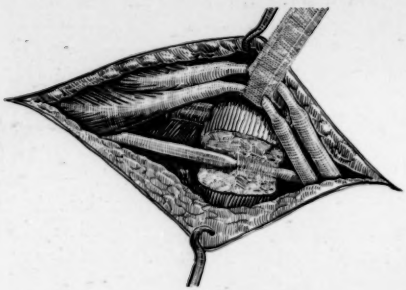


FIG. 3

Stenosis of all tendons.

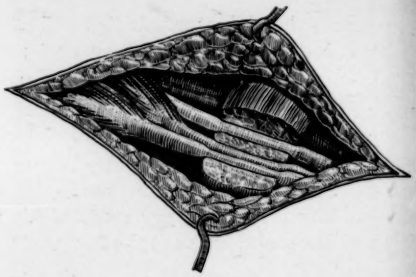


FIG. 4

An aberrant tendon occupies a separate osseofibrous canal.

PATHOGENESIS

It is generally accepted that trauma to the tendon sheath is the cause of this disease. Finkelstein was able to produce the disease experimentally in rabbits by thermal, mechanical, and chemical trauma. The superficial position of the tendons certainly makes them susceptible to various direct contusions. However, repeated tearing of the tendon sheath from stretching probably represents the cause in most cases.

After the ligament and the tendon sheath have become thickened, the tendons are so choked that normal excursion is impossible. If choking continues until no tendon excursion can be carried out at all, the tendons become fixed in the osseofibrous canal by peritendinous and intertendinous adhesions. Unlike the stenosis of flexor tendons of the fingers and thumb, snapping is not characteristic.

VARIATIONS

The tendons may vary in their relations to each other and the location of the area of stenosis may also vary.

The following variations in *relationship of the tendons* to each other have been observed:

1. The abductor pollicis longus and the extensor pollicis brevis may occupy separate osseofibrous canals (Fig. 1);

2. The abductor pollicis longus and the extensor pollicis brevis may lie together in one osseofibrous canal (Fig. 2);

3. An aberrant tendon may lie deep in the osseofibrous canal (Fig. 3) with the abductor pollicis longus and the extensor pollicis brevis, in which case it usually has a separate osseofibrous canal in the distal part of the main canal;

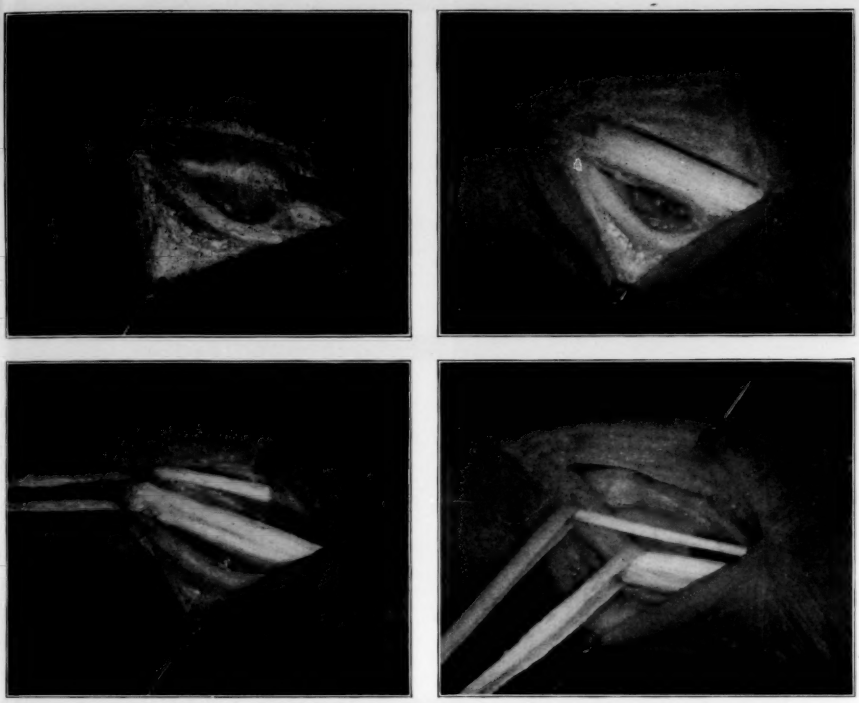


FIG. 5

Stenosis of the aberrant tendon only in its separate compartment deep in the common canal. Note groove director easily admitted under dorsal carpal ligament with no stenosis of large first compartment.

4. An aberrant tendon may be present in a separate osseofibrous canal (Fig. 4), in which case it is usually dorsal to the main osseofibrous canal housing the abductor pollicis longus and the extensor pollicis brevis. The aberrant tendon may actually be the extensor pollicis brevis, and the abductor pollicis longus may appear as a double tendon.

The following variations in the *area of stenosis* have been noted:

1. There may be stenosis of the common sheath of the abductor pollicis longus and the extensor pollicis brevis as they lie together in one canal (Fig. 2);

2. Stenosis may involve the abductor pollicis longus, and the extensor pollicis brevis, as well as the aberrant tendon as it lies deep in the main canal in its separate compartment (Fig. 3);

3. Stenosis may involve only the aberrant tendon (Fig. 5);

4. If the abductor pollicis longus and the extensor pollicis brevis lie in separate canals, stenosis may involve either tendon or both tendons (Figs. 6 and 7);

5. Stenosis may involve the aberrant tendon in a separate osseofibrous canal dorsal to the common canal of the abductor pollicis longus and the extensor pollicis brevis (Fig. 4);

6. Stenosis may involve both the aberrant tendon in its separate canal and the abductor pollicis longus and the extensor pollicis brevis in their common canal (Fig. 8).

EXAMINATION

A constant finding is point tenderness about one-half inch proximal to the tip of the radial styloid process. Swelling is usually present in the same region, but may be obscured

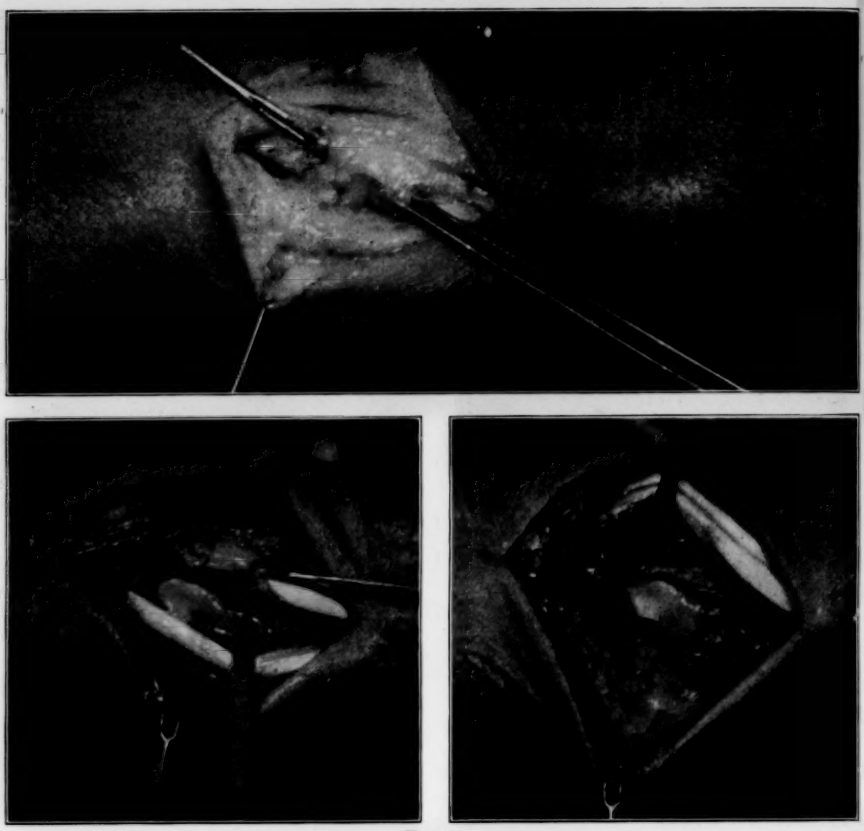


FIG. 6
Stenosis of extensor pollicis brevis only.

by obesity. In testing the patient, it should be borne in mind that any force which tends to move the tendons either distally or proximally through the constricted area will result in pain in the region. Traction on the thumb and ulnar deviation of the wrist exaggerate pain. In severe cases, the patient is often unable to touch the tip of the thumb to the base of the little finger. Acute passive flexion or active extension against resistance is painful. The pinch may be weak and painful. When the patient puts both pronated hands upon the examination table, more radial deviation may be noted on the side of the disease. The hand grip is weak. A negative roentgenogram is usual, although in two reported cases [9] calcification was noted. It must be remembered that the pain caused by stretching the tendon sheath can be reproduced in the normal individual by flexing the thumb to the base of the little finger, closing the fingers tightly over the thumb, and deviating the wrist to the ulnar side.

TREATMENT

A few spontaneous cures have been reported [2, 8]. Conservative treatment, such as immobilization in plaster with the thumb in the position of function, appears to give permanent relief in about 25 per cent. of the cases. However, it is the author's belief that only in the very early cases does this method give relief. Operation is the method of choice in cases which do not respond to conservative treatment or for patients who do not wish to go through a long trial period of conservative treatment. The operation is simple and

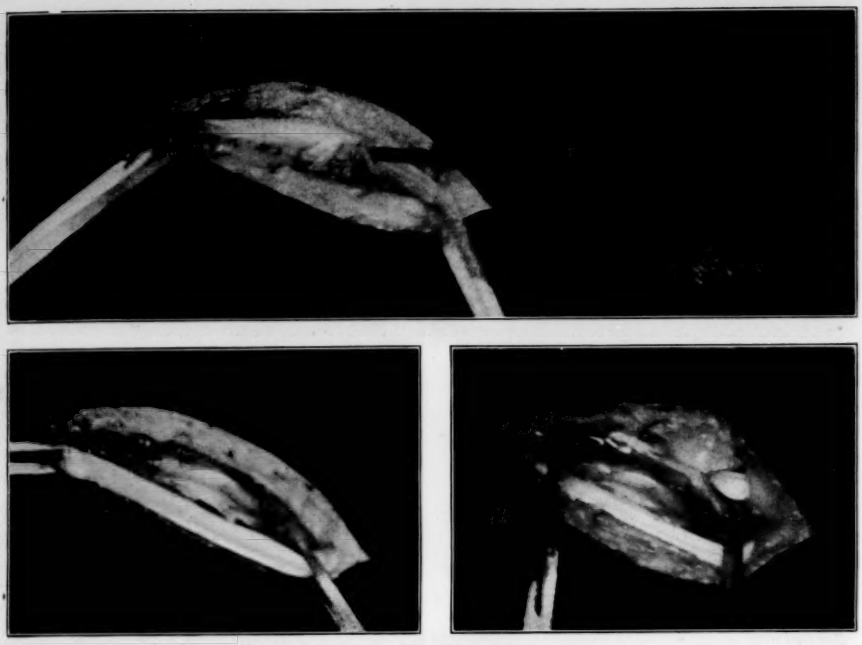


FIG. 7

Stenosis of both abductor pollicis longus and extensor pollicis brevis in separate canals.

in many ways similar to the Rammstedt procedure for pyloric stenosis in the infant. The simplicity of the operation is no doubt responsible for its high degree of success. A cure can be expected, providing all stenosed tendons are found and freed.

Technique of Operation

Under local infiltration with novocain and with a pneumatic arm tourniquet, either a longitudinal or a transverse incision is made through the skin over the radial styloid process. A transverse incision is preferable, since a better scar results. The tendon sheath is nicked just distal to the dorsal carpal ligament, and a groove director is inserted to determine the area of stenosis. The area of stenosis is then divided longitudinally. A piece of umbilical tape is then slipped under the tendons and used to retract them from their bed. This is less traumatic than use of a metal instrument on the tendons. Inspection is carried out for the aberrant tendon which may lie deep in, or in close proximity to, the osseofibrous canal, representing the first compartment. The tendon must of course be adequately freed. The dorsal aspect of the osseofibrous canal is explored, and sometimes a hidden tendon will be found. (The author has had nine such cases where this tendon was stenosed and would have been overlooked had exploration not been carried out. He has not yet excised the aberrant tendon in any case and in a total of nineteen cases of aberrant tendon, there has been no recurrence of symptoms.)

The tendons are then replaced in their bed; but, before the wound is closed, the tourniquet is released and the patient is asked to actively move the thumb to insure that function has been reestablished. Only skin and subcutaneous tissue are closed with interrupted sutures. In doing the operation, care should be taken not to injure the radial nerve, the cephalic vein, or the radial artery.

Postoperative Care

A bandage is applied, and the patient is allowed active motion of the thumb im-

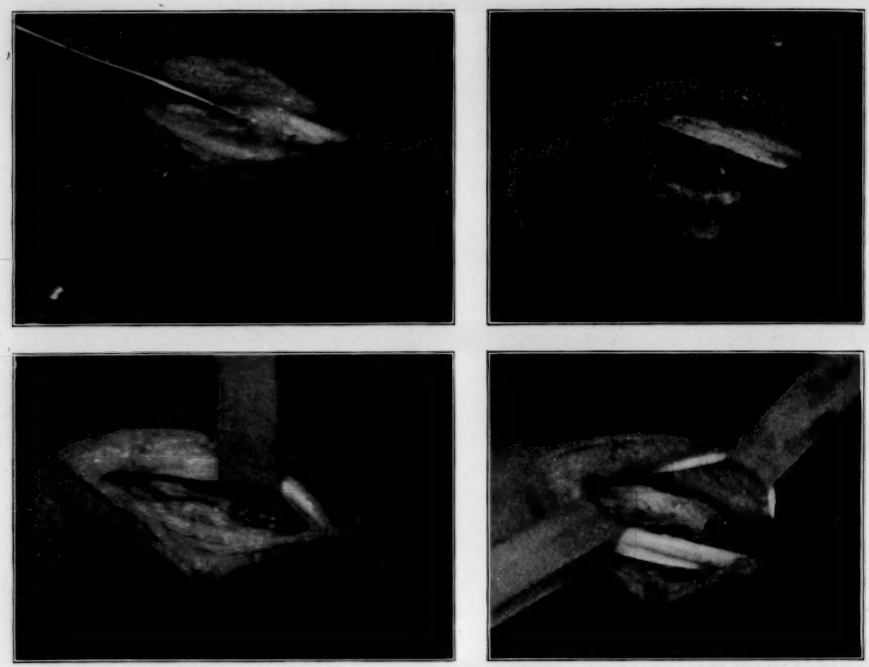


FIG. 8

Stenosis of abductor pollicis longus and extensor pollicis brevis in one canal and aberrant tendon in separate canal. Without exploration, this tendon would have been overlooked.

mediately. It is remarkable that painless thumb motion is usually present from the time that the stenotic band is divided. The sutures are removed on about the seventh post-operative day.

SUMMARY

At operation, some variations have been observed in the relation of the abductor pollicis longus and the extensor pollicis brevis and the aberrant tendon, one to the other. The area of stenosis has also been found to vary.

REFERENCES

1. BUNNELL, STERLING: Surgery of the Hand, Ed. 2. Philadelphia, J. B. Lippincott Co. 1948.
2. COTTON, F. J.; MORRISON, G. M.; and BRADFORD, C. H.: De Quervain's Disease, Radial Styloid Tendovaginitis. New England J. Med., **219:** 120–123, 1938.
3. DE QUERVAIN: Ueber eine Form von chronischer Tendovaginitis. Correspondenz-Blatt f. Schweizer Aerzte, **25:** 389–394, 1895.
4. FINKELSTEIN, HARRY: Stenosing Tendovaginitis at the Radial Styloid Process. J. Bone and Joint Surg., **12:** 509–540, July 1930.
5. GRAY, HENRY: Anatomy, Descriptive and Surgical, Ed. 13, p. 491. Philadelphia, Lea Bros. & Co., 1893.
6. NUSSBAUM ADOLF: Beitrag zur Tendovaginitis stenosans fibrosa des Daumens (de Quervain). Bruns' Breiträge z. Klin. Chir., **104:** 140, 1917.
7. PARSONS, F. G., and ROBINSON, A.: Eighth Report of the Committee of Collective Investigation of the Anatomical Society of Great Britain and Ireland for the Year 1897–1898. J. Anat. and Physiol., **33:** 189–203, 1899.
8. PATTERSON, D. C.: De Quervain's Disease; Stenosing Tendovaginitis at the Radial Styloid. New England J. Med., **214:** 101–103, 1936.
9. SCHNEIDER, C. C.: Stenosing Fibrous Tendovaginitis over Radial Styloid (de Quervain). Surg., Gynec., and Obstet., **46:** 846–850, 1928.
10. WAGENSEIL, F.: Untersuchungen über die Muskulatur der Chinesen. Ztschr. Morphol. und Anthropol., **36:** 39–150, 1936.

ANATOMICAL AND CLINICAL STUDY OF THE VARIATIONS IN THE INSERTIONS OF THE ABDUCTOR POLLICIS LONGUS TENDON, ASSOCIATED WITH STENOSING TENDOVAGINITIS

BY THOMAS LACEY II, M.D., LOUIS A. GOLDSTEIN, M.D., AND CHARLES E. TOBIN, PH.D.,
ROCHESTER, NEW YORK

From the Department of Surgery, Division of Orthopaedics, and the Department of Anatomy, University of Rochester School of Medicine and Dentistry, Rochester

Bunnell, in 1944, first called attention to the importance of the "aberrant tendon" which occurs in the sheath common to the abductor pollicis longus and the extensor pollicis brevis at the radial styloid. He mentioned comparative anatomical findings of a split insertion of the abductor pollicis longus tendon in the base of the first metacarpal and multangular bones in the chimpanzee, the gorilla, and the gibbon, with the obvious implication as regards the aberrant tendon in the human being. In his series of twenty-two cases of stenosing tenosynovitis of the abductor pollicis longus tendon, a single aberrant

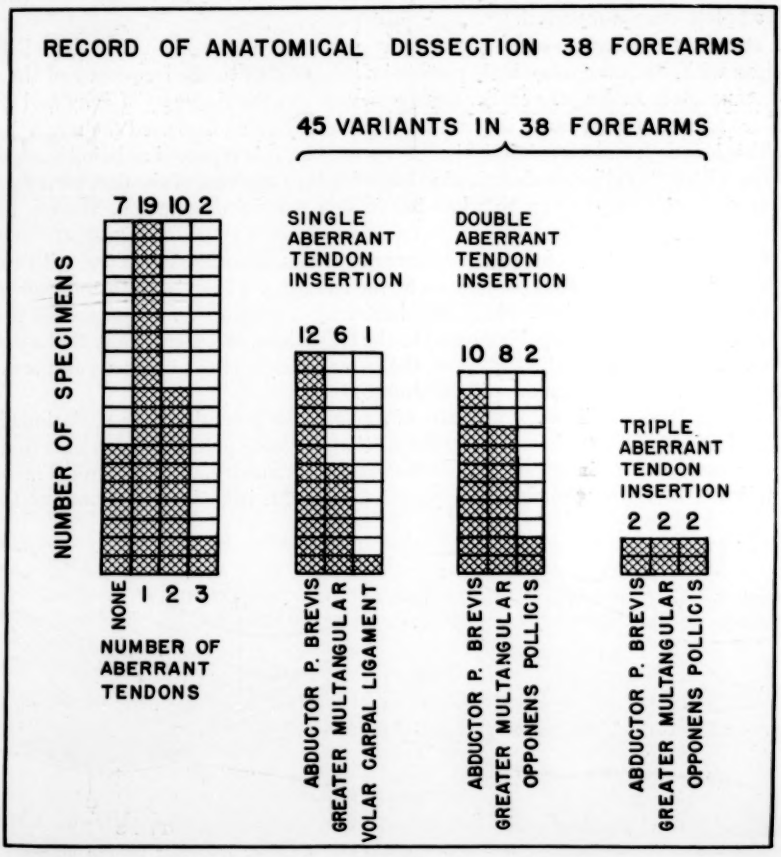


CHART I

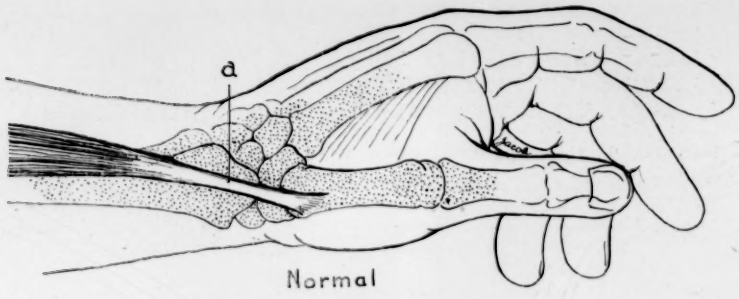


FIG. 1

a: Abductor pollicis longus

tendon is recorded in twelve of the twenty-two cases, with various insertions into the carpal scaphoid (navicular), the trapezium (greater multangular), the transverse carpal ligament, or into the fascia over the thenar eminence. In all cases in which an aberrant tendon was found, excision of the aberrant tendon was performed at tenolysis and in all twenty-two cases complete cure is reported.

A search of the human-anatomy texts in current use reveals an abundant listing of variations with, however, very little precise information as to the frequency of the variations encountered. Among the earlier texts reviewed was the *Anatomy* of John and Charles Bell of 1811. In this work credit is given to Albinus for having first used the name "abductor pollicis longus". In Bell's description of the tendon, it is reported as being composed of four slips. These four slips are described as inserting into the base of the first metacarpal,—a rather disappointing ending to what began as a fruitful description. Meckel, in 1832, describes " . . . two or three slips, the strongest of which is also the most anterior . . . attached . . . to the base of the first metacarpal bone; the other two blend with the posterior extremity of the antagonist muscles of the thumb. . . . It is often more or less divided into two bellies, each of which terminates by a tendon. . . . Sometimes they are attached to the first metacarpal bone and to the trapezium. We more rarely find a digastric abductor of the thumb which arises from the outer condyle of the humerus and is inserted into the base of the first phalanx of the thumb."

Wood, in 1865, published the results of a search for general muscle variations in seventy-two human subjects, in which he found the abductor pollicis longus insertion to be by two or more tendons in 68 per cent. of the subjects studied. Later anatomical records do not duplicate the thoroughness of this report. Tendinous insertions by from one to three

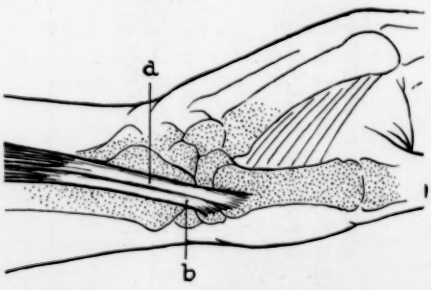


FIG. 2

a: Abductor pollicis longus
b: Slip to the greater multangular

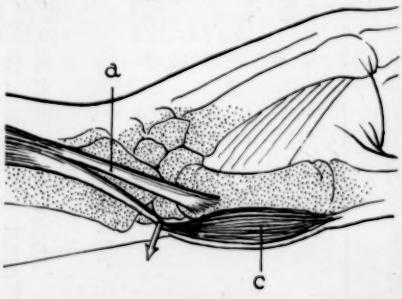


FIG. 3

a: Abductor pollicis longus
c: Abductor pollicis brevis

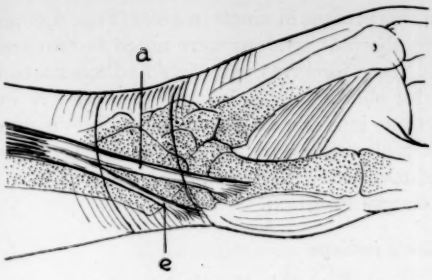


FIG. 4

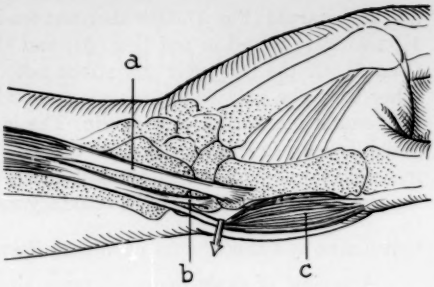


FIG. 5

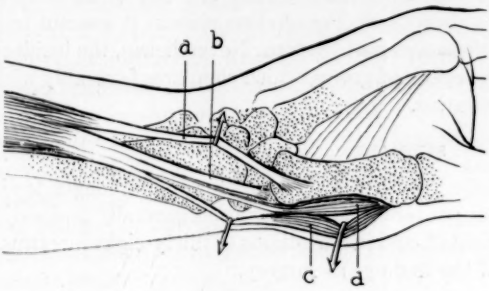


FIG. 6

Fig. 4: *a*: Abductor pollicis longus
e: Slip to volar carpal ligament

Fig. 5: *a*: Abductor pollicis longus
b: Slip to greater multangular
c: Abductor pollicis brevis

Fig. 6: *a*: Abductor pollicis longus
b: Greater multangular
c: Abductor pollicis brevis
d: Slip to opponens pollicis

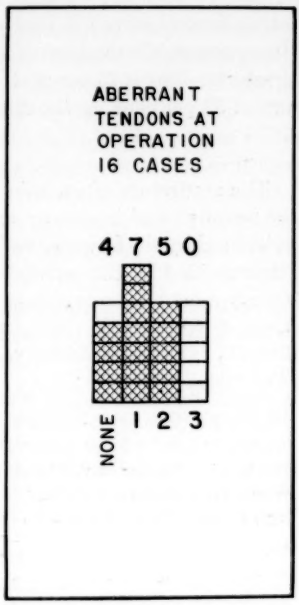


CHART II

slips into the greater multangular, abductor pollicis brevis, opponens pollicis, are described in detail, with tabulation of the frequency of variants encountered. This represents by far the most complete and important listing of variations in the literature.

In Henle's *Anatomy* (1871), the statement is made that the insertion is not infrequently doubled. A number of variations are mentioned but are not tabulated. In Hyrtl's *Anatomy* (1887), the insertion of the abductor pollicis longus is not infrequently described as a slip to the trapezium (greater multangular), or to the abductor pollicis brevis, or even to the opponens. This succinct statement is in agreement with modern anatomical texts but, like them, only hints at frequency.

Because of diverse findings in the literature, and at tenolysis, regarding the number and size of the aberrant tendons, it was felt worth while to reinvestigate the insertion of the abductor pollicis longus tendon in a sufficient number of specimens to arrive at a more concise expression of the anatomical variations involved.

CADAVER DISSECTION

Special attention was paid to the insertion of the abductor pollicis longus and its variants in dissection of thirty-eight human forearms. Of these thirty-eight forearms, only seven were "normal" in the sense of having a single tendinous insertion on the base of the

first metacarpal (Fig. 1). One aberrant tendon was present in nineteen arms (Figs. 2, 3, and 4); two were found in ten (Fig. 5); and three aberrant tendons were noted in two arms (Fig. 6). Of the forty-five variations noted in these forearms, only five had insertions in other than the greater multangular or abductor pollicis brevis. In none of these five was the tendon more than a mere slip. The insertions into the abductor pollicis brevis numbered twenty-four and those to the greater multangular sixteen (Chart I). Tendinous insertion on the greater multangular and abductor pollicis brevis varied from a slip to a size comparable to that of the ordinary metacarpal insertion.

Correlation of Cadaver Dissection with Operative Findings

A review of cases operated upon since our staff at this Hospital has become more aware of these aberrant tendons reveals an interesting correlation with the observed incidence of aberrant tendons at the dissecting table (Chart II). One or more aberrant tendons were observed in twelve of sixteen cases. For obvious reasons it was not possible to trace accurately the insertions of these aberrant tendons. Nevertheless, the incidence of aberrant tendons is 75 per cent. in the operated group, which compares favorably with the figure of 82 per cent. in the dissected arms.

SUMMARY

The occurrence of variations in the insertion of the abductor pollicis longus tendon is more common and in greater number per forearm than has been generally realized. This is evidenced by the frequency of variants found in dissections of thirty-eight forearms, and further verified by the correlation of the findings at surgery.

REFERENCES

1. Bell, J., and Bell, C.: Anatomy. London, Longman, Hurst, Rees, Orme and Brown; and T. Codell and W. Davies, 1811.
2. Bunnell, Sterling: Surgery of the Hand, Ed. 1. Philadelphia, J. B. Lippincott Co., 1944.
3. Henle, J.: Anatomie. Braunschweig, F. Vieweg, & Sohn, 1871.
4. Hyrtl, J.: Lehrbuch der Anatomie. Wien, W. Braumueller, 1887.
5. Meckel, J. F.: Anatomy. Philadelphia, Carey & Lea, 1832.
6. Wood, J.: Variations in Human Myology observed during the Winter Session of 1867–68 at King's College, London. Proc., Royal Soc., London, **16:** 483–525, 1868.

SUBTROCHANTERIC OSTEOTOMY AND SPLINE FIXATION FOR CERTAIN DISABILITIES OF THE HIP JOINT

A Preliminary Report *

BY MATHER CLEVELAND, M.D., DAVID M. BOSWORTH, M.D., AND A. DELLA PIETRA, M.D., NEW YORK, N. Y.

From the Orthopaedic Service, St. Luke's Hospital, New York City, and St. Vincent's Hospital, Staten Island

The present investigation has arisen as a result of the report of Dickson, in January 1947, at the meeting of The American Academy of Orthopaedic Surgeons. The principle of removal of shearing stress in fracture of the neck of the femur has in the past been recognized by many surgeons. As early as 1897, Royal Whitman spoke of the sinking of the neck and suggested subtrochanteric osteotomy. While the authors agreed with the principle of removing shearing stress by replacement of the head in direct alignment with the shaft, they felt that the additional bone-grafting at the fracture site in this group of patients was not wise. The additional operative time and trauma associated with such grafting and the possibility of further interference with circulation of the head fragment seemed to contra-indicate it. Therefore, in only one of the cases in this series was such grafting done, and in this case the result was non-union and loss of the head fragment by almost complete aseptic necrosis.

A total of thirty-five hips have been treated by the method of rotational osteotomy and internal fixation. There was one postoperative infection, but no operative mortality. Operation has been performed for the following conditions:

1. Non-union of intracapsular fracture of the neck of the femur (twenty-two patients); subtrochanteric fracture of the femoral shaft (three patients); and intertrochanteric fracture with non-union (one patient);
2. Aseptic necrosis of the head of the femur (one adult and one child);
3. Congenital coxa vara in children (two patients);
4. Residual coxa plana (two patients);
5. Old severely slipped femoral epiphysis (one patient);
6. Fractures of the femoral neck in children (two patients).

Internal fixation was secured at first by means of a high-angled Jewett nail (fifteen operations). Thereafter a straight "spline" † was developed, in a large size for adults and a smaller size for children. This straight, flat spline (a prototype of the blade-plate of Blount) was soon modified by the attachment of a rib or flange to its undersurface to prevent the edge from sweeping through the femoral head, as occurred on one occasion. The spline has been used on the last twenty patients (thirteen adults and seven children).

1. *Non-Union of Intracapsular Fractures, Trochanteric Fractures, and Subtrochanteric Fractures, in the Adult*

A. Intracapsular fractures of the neck of the femur with non-union were encountered in twenty-two instances. Of the twenty-two, five fractures were originally reduced and the fragments fixed with a Smith-Petersen nail by the authors. The seventeen cases were transferred from other hospitals, where they had been subjected to varying forms of treatment.

* Read at the Annual Meeting of The American Orthopaedic Association, Virginia Beach, Virginia, May 23, 1950.

† Webster's Dictionary: (1) A rectangular piece or key fitting into a groove in the hub of a wheel and a similar groove in a shaft, so that, while the wheel may slide endwise on the shaft, both must revolve together.

Audel's Mechanical Dictionary: A feather or long fixed key set in a shaft, so that the hub or part fitted on the shaft may be slid along it lengthwise, but must always revolve with it.

Figs. 1-A to 4-C: Roentgenograms of four patients with non-union difficult to treat, who secured good function of hips with solid union by means of internal fixation and rotational osteotomy.

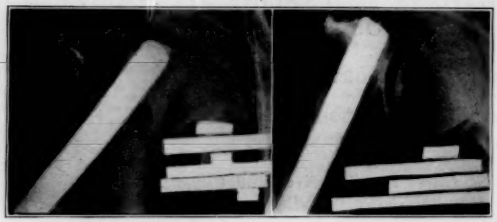


FIG. 1-A FIG. 1-B

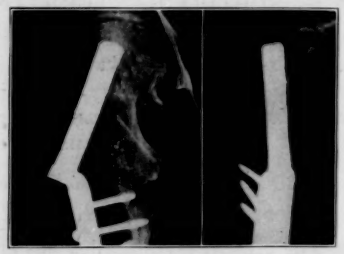


FIG. 1-C FIG. 1-D

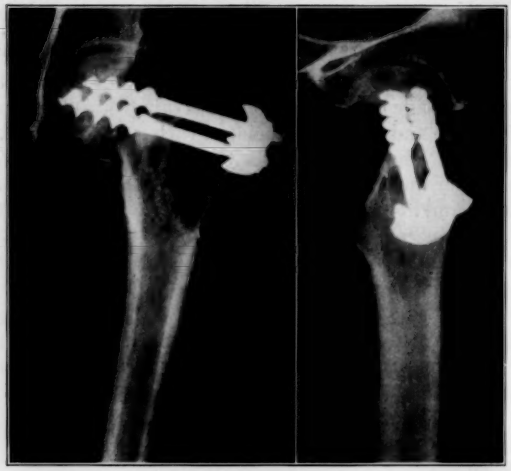


FIG. 2-A FIG. 2-B

FIG. 2-C

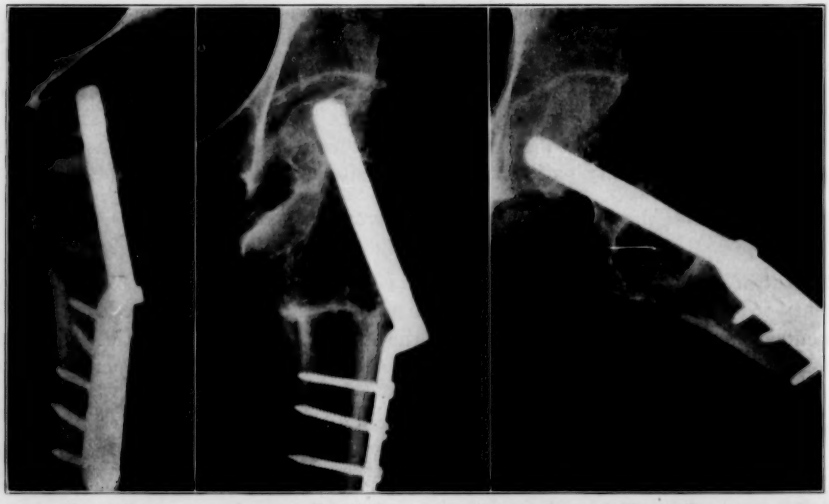


FIG. 2-D FIG. 2-E FIG. 2-F

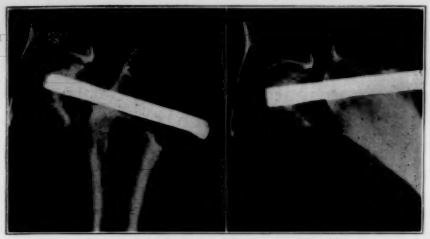


FIG. 3-A

FIG. 3-B

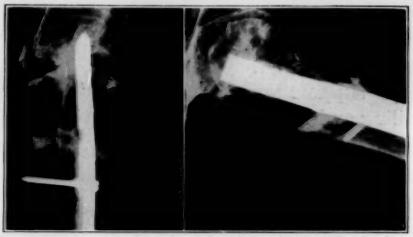


FIG. 3-C

FIG. 3-D

Jewett-Nail Fixation

A typical hexagonal osteotomy was attempted on eight occasions, 60 degrees of rotation being secured each time. In seven of the eight cases, the result was not satisfactory. The hexagonal osteotomy was, therefore, discarded. Thereafter the Jewett nail and simple subtrochanteric osteotomy were used in an additional four cases, in an attempt to gain more than 60 degrees of rotation. These results were more successful.

FIG. 4-A

FIG. 4-B

FIG. 4-C

The Jewett nail was used in a total of twelve instances. Included among these patients were the seven failures mentioned in the preceding paragraph. Four had further non-union (one with breakage of the metal prosthesis), two had aseptic necrosis, and one had infection. There were five successes in which the hip was excellent and the fracture of the neck of the femur united. The percentage of excellent results where a Jewett nail was used was, therefore, 41.7. In early cases, where only 60 degrees of rotation was secured, the percentage of excellent results was only 12.5. Later, when more than 60 degrees of rotation was obtained, the results were excellent in all cases.

In four of the patients in whom non-union developed, the nails were removed, and the results were comparable to those achieved by a good McMurray osteotomy. In the patient whose femoral head was lost through infection, a stable weight-bearing hip with minimal discomfort resulted. In the one with a broken prosthesis, non-union developed, but a stable hip did not result; the head again slipped off its neck support, and the patient remained badly disabled.

While it is well to consider the failures more carefully than the successes, two of the latter are described to denote what can be accomplished, and to indicate that the appearance of the bone structures before osteotomy is not a definite indication of what the result may be.

The first patient had displacement within seventeen days after reduction and fixation with a Smith-Petersen nail (Figs. 1-A and 1-B). The bone structures appeared atrophic and presented little material for retention of a metal support. The patient also had marked rheumatoid arthritis. Despite these facts, a Jewett nail was used with trochanteric osteotomy (Figs. 1-C and 1-D), securing 75 degrees of rotation. The latest roentgenograms, taken two years and eight months after operation, showed the condition to be excellent; this was also apparent on examination of the patient.

Another patient had sustained a fracture of the neck of the femur in December 1946; this was reduced and the fragments fixed with a Smith-Petersen nail. The nail was replaced by two bolts, ten days thereafter (Figs. 2-A and 2-B); six months later, there was non-

union (Figs. 2-C to 2-F). A high-angle Jewett nail, placed high in the trochanter and directed downward, was used with osteotomy, resulting in approximately 90 degrees of rotation. At the time of operation the femoral head did not look capable of holding further metal support and was firmly fixed in the socket by apparent adhesions. Two years after nailing and rotational osteotomy, the site of non-union had healed. The patient was bearing weight, had an excellent range of motion in the hip, and was asymptomatic.

By this time it seemed certain that rotation beyond 60 degrees was necessary if shearing force was to be eliminated and the percentage of successes increased. For such further and complete rotation of the head fragment into the vertical position, a new prosthesis was needed (Fig. 5). The blade-plate of Blount was available, but greater rigidity, less flexibility, and complete removal of the electrolytic action of steel were desired. Therefore blade-plates or splines were made in Vitallium.

Spline Fixation

Nine patients with non-union of intracapsular fractures of the neck of the femur were treated with osteotomy and the use of a spline as an internal prosthesis. In each of these patients a simple subtrochanteric osteotomy was done. Four have already had unsatisfactory results and five show prospects of excellent results. Two of these five were treated too recently to show union of the intracapsular fracture, but the position, appearance of head fragment, and lack of any signs of aseptic necrosis when compared with previous cases indicate success. Three of the five good results are complete and show union of the ununited fracture of the neck of the femur, the femoral head straight above the shaft, and excellent clinical and weight-bearing hips (Figs. 3-A to 4-C).

Of the four failures, one was due to the use of the first spline, which had no rib to prevent slicing of the sharp edge sideways through the femoral head. In this case the head is still resting above the shaft and trochanteric fragment, in the position of a McMurray osteotomy; although the patient has a decreased range of motion, he is practically asymptomatic and has a stable weight-bearing gait. The other three patients classified as having poor results had gradual protrusion of the spline through the femoral head. However, these three, as well as the previous case, show good clinical results as far as weight-bearing on the hip is concerned. Protrusion of the spline through the head took place with minimal erosion of the upper portion of the acetabular roof. In one the spline has already been removed and in the other two it will probably have to be removed. Therefore, of the patients in whom a spline was used and an attempt made to secure full rotation of the head above the line of the femoral shaft, *five of nine have excellent results* (55.5 per cent.), *and all have useful weight-bearing structures.* Further improvement is probable

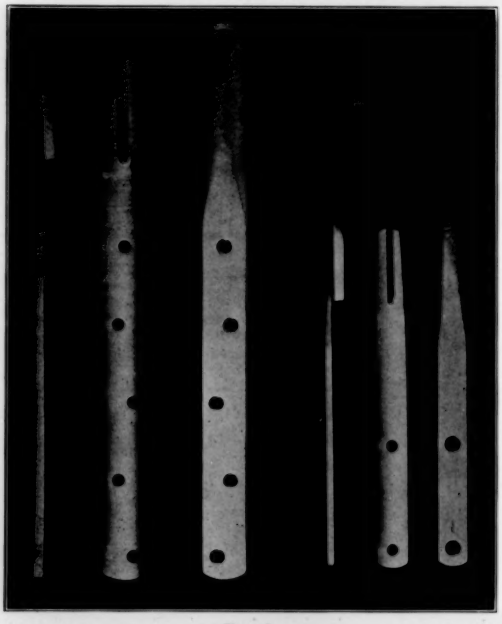


FIG. 5

Splines for adults and children. Note rib on undersurface to prevent slicing of the spline through the head.

FIG. 6-A FIG. 6-B FIG. 6-C

FIG. 6-D FIG. 6-E FIG. 6-F FIG. 6-G

Roentgenograms of a subtrochanteric pathological fracture in which two Jewett nails were broken and four operative attempts were required before coxa valga was secured with rotational osteotomy and a spline. Union resulted.

with added experience in selection of cases, more facile operative technique, and better placement of the spline.

B. The one patient with non-union of a trochanteric fracture died six weeks after operation, of a cerebral accident. She had had hemiplegia before suffering her fracture and the terminal occurrence resembled another cerebral hemorrhage. At the time of her death, roentgenograms showed satisfactory position of the fracture fragments.

C. Three patients with non-union resulting from subtrochanteric fracture of the femur were treated with the spline and osteoplasty at the site of non-union. Two of these patients have been operated upon too recently for the end results to be considered. In one the end result is known and in view of the difficult situation, the case needs some description (Figs. 6-A to 6-G). She suffered a subtrochanteric fracture of the fatigue stress type associated with syphilis of the central nervous system. On two occasions Jewett nails became fractured and displaced, even though weight-bearing was not permitted for five months, with apparent union each time. A straight bone plate was used, with correction of almost all of the coxa vara; however, because some coxa vara still persisted, the prosthesis tore out of the side of the head and neck and non-union occurred for a fourth time. Complete coxa valga was achieved with a spline, the head swinging outward beyond the line of the femoral shaft. This resulted in union which has successfully stood the test of weight-bearing, despite the fact that fatigue stress with pathological fracture developed in the opposite tibia. The second of these patients suffered a war wound and a compound fracture of the femur. On two occasions bone-grafting was done and union was secured, but fracture again occurred through sclerotic bone after simple resumption of weight-bearing. By the use of a spline, lateral bowing was reversed; and it appears that union will be successful. The third case has only recently been treated and no conclusions can be drawn. It would ap-

pear, therefore, that in subtrochanteric fractures with non-union the outlook may be improved by removing the normal coxa vara together with its bending strain.

2. *Aseptic Necrosis of the Head of the Femur*

Where aseptic necrosis of the upper outer corner of the head of the femur has occurred and the residual head appears intact, it would seem that rotation of the uninvolved portion of the head up into weight-bearing position by the use of a spline and subtrochanteric

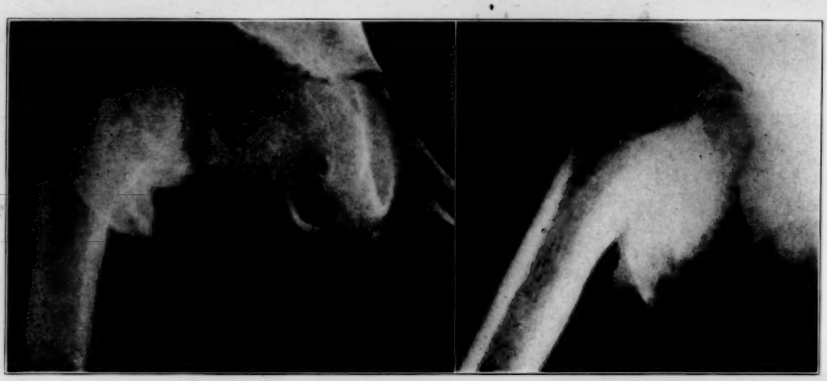


FIG. 7-A FIG. 7-B

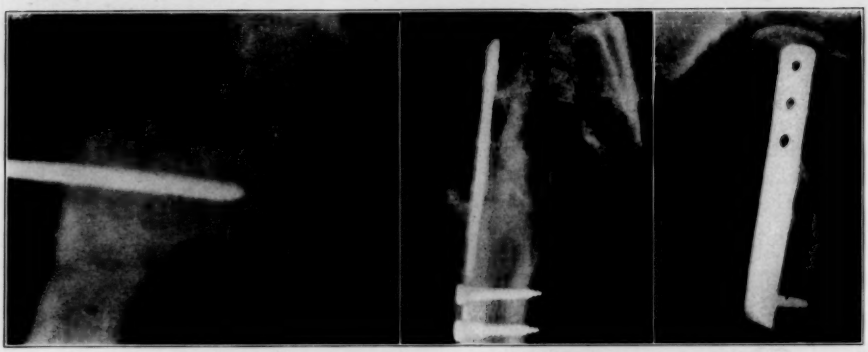


FIG. 7-C FIG. 7-D FIG. 7-E

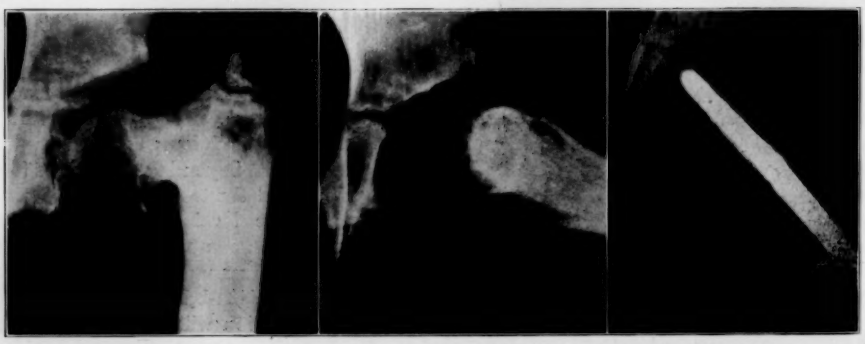


FIG. 8-A FIG. 8-B FIG. 8-C

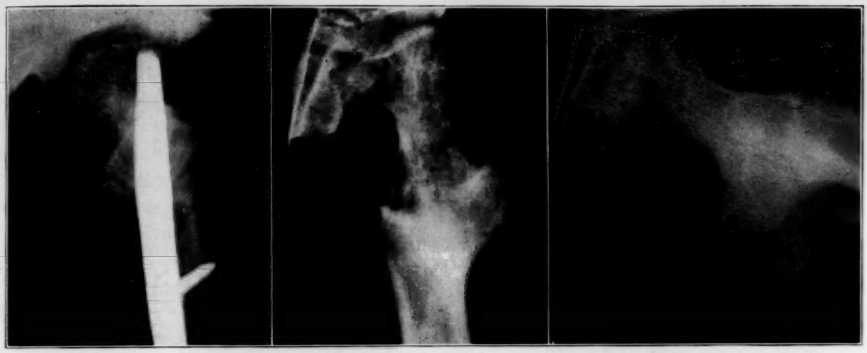


FIG. 8-D FIG. 8-E FIG. 8-F

Figs. 7-A to 8-F: Roentgenograms illustrating the use of a spline and rotational osteotomy in two instances of congenital coxa vara.

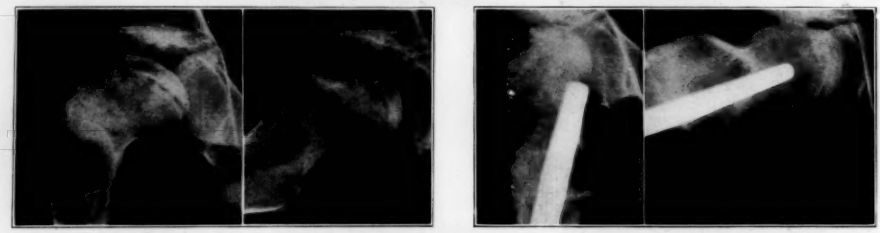


FIG. 9-A FIG. 9-B FIG. 9-C FIG. 9-D

Deformity of old coxa plana may be corrected with spline and rotational osteotomy by removing the flattened portion of the head and putting the rounded pointed portion up into the acetabulum.

osteotomy could justifiably be considered. One such adult has had this procedure in an attempt to decrease her pain and add weight-bearing stability. No end result can be shown, but the mechanical situation seems satisfactory and the patient is at present bearing weight on crutches without pain. One other patient with aseptic necrosis has spline fixation and osteotomy, but the case is to be considered hereafter among fractures of the neck of the femur in children.

3. *Congenital Coxa Vara* (Figs. 7-A to 8-F)

It was but a step from the surgery described to use of the spline and subtrochanteric osteotomy for correction of congenital coxa vara. Two patients with congenital coxa vara have been so treated and both have excel-

FIG. 10-A FIG. 10-B FIG. 10-C FIG. 10-D

FIG. 11-A

FIG. 11-B

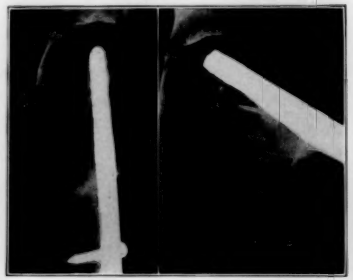


FIG. 11-C

FIG. 11-D

FIG. 11-E

FIG. 11-F

FIG. 12-A

FIG. 12-B

FIG. 12-C

FIG. 12-D

Figs. 10-A to 12-F: Three fractures of the neck of the femur in children treated by internal fixation and rotational osteotomy. Figs. 12-C and 12-D show aseptic necrosis which seemed to heal rapidly following removal of the area of aseptic necrosis from the weight-bearing position.

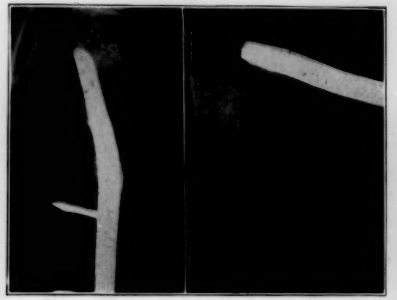


FIG. 12-E

FIG. 12-F

lent early results. The first patient had had subtrochanteric osteotomy, with displacement and further shortening of the lower extremity, without the coxa vara being removed. Since no spline had been developed small enough for a child, an ordinary Venable type of plate was inserted at almost 90 degrees; osteotomy was done three-quarters of an inch below; and complete derotation of the head and neck fragment was secured. Fifteen months after operation an excellent hip had been secured. The epiphyseal line is still open.

The procedure is extremely difficult, especially the abduction of the distal portion of the femur to meet the plate without displacement of the fragments. Bilateral saddle traction was used in both patients for six weeks, and thereafter they were bearing weight on crutches without brace support.

The second patient had a similar procedure done with the smaller sized spline used for children. Subsequently a supracondylar osteotomy was performed for marked external rotation of the lower extremity. The spline has since been removed. Both patients have an excellent range of motion of the hip and essentially normal gait. Lengthening of the lower extremity was secured by the procedure,—one and one-half inches in the first patient and three-quarters of an inch in the second.

4. *Old Residual Coxa Plana* (Figs. 9-A, 9-B, 9-C, and 9-D)

Two patients with advanced changes from epiphysitis of the femoral head were treated with rotational osteotomy and a spline to remove the more involved portion of the head from contact with the acetabulum, to place the lower uninvolved margin of the head up into the weight-bearing position, and to remove the bulky expanded portion of the head from the acetabulum and replace a smaller pointed portion in relationship thereto. The anatomical realignment of structures appears to be good. No final conclusions can be drawn as to end results at this time.

5. *Old Slipped Femoral Epiphysis*

A hip which has suffered the changes incident to old slipped femoral epiphysis of severe degree combines the problems involved in both congenital coxa vara and coxa plana. One patient with this condition has recently been operated upon, the spline and osteotomy being used. The mechanical situation appears good, but an end result cannot be reported.

6. *Fractures of the Neck of the Femur in Children* (Figs. 10-A to 12-F)

Fractures of the neck of the femur in children represent a separate and considerable problem. The results of treatment of such fractures in the past have been uniformly poor. Three of these patients have been treated with rotational osteotomy and internal fixation, and all three have done well. In two of them the results are and have been for some time excellent, with full weight-bearing and normal activities. The first of these was a twelve-year-old girl, markedly overweight, who had spent two and one-half months in a plaster spica and had had one month of traction in another hospital. She came to the authors with non-union of the fractured neck of the femur. She was treated before splines were developed and a Jewett nail was used, securing almost complete derotation and vertical placement of the head over the femoral shaft. Gradually the fracture fragments united and she now has an essentially normal hip as regards motion and weight-bearing. Although three-quarters of an inch in length was gained by the procedure, she still has residual shortening of one and one-quarter inches.

The second child had acute fracture of the neck of the femur when first seen at the age of five. A spline and osteotomy were used as the primary procedure. The spline was removed three months after operation. Now, thirteen months after operation, she has union with a normal hip except for 30 degrees of loss of internal rotation. Her epiphysis is not closed. She engages in normal activity and has no shortening. It is noteworthy that the

first little girl was treated by non-operative means for four months and still had non-union, while the second patient had solid union and was ambulatory in three months.

The third child came to us four months after injury, with non-union resulting from an intracapsular fracture. Bone-grafting across the fracture site was done with a tibial strip, and this resulted in aseptic necrosis of the head of the femur above the graft. Since the lower portion of the head and neck seemed to be intact, and in view of previous experience with osteotomy and the use of the spline, it was decided that this procedure be used. It was felt that this would place the lower uninvolved portion of the head and neck in weight-bearing contact with the socket and relieve the pressure over the aseptic necrotic portion of the head. Rapid improvement in the aseptic necrosis of the head with re-establishment of more normal bony texture has taken place without collapse or change in the portion of the head rotated up to receive pressure from the acetabulum. This boy is still non-weight-bearing on crutches (but cheats). The involved lower extremity is now one-half inch longer than the opposite or normal limb. It is probable that growth damage will more than wipe out this gain in the future.

CONCLUSIONS

1. Rotational osteotomy and internal fixation would seem to have a definite place in the treatment of non-union of intracapsular fractures of the neck of the femur, delayed union or non-union of trochanteric fractures, and non-union of subtrochanteric fractures. It would seem to be the treatment of choice for congenital coxa vara and for fractures of the neck of the femur in children. It may eventually be shown to have usefulness in hips having old deformed changes of coxa plana, in certain instances of aseptic necrosis, or in old severe slipping of the femoral epiphysis.

2. If rotational osteotomy is to be done, it should be performed so as to elevate the head of the femur as nearly in complete alignment with the shaft as possible (90 degrees).

3. The procedure is extensive, and difficulty may be encountered in securing abduction without displacement of fragments due to tension of soft tissues.

REFERENCES

DICKSON, J. A.: The High Geometric Osteotomy, with Rotation and Bone Graft, for Ununited Fractures of the Neck of the Femur. A Preliminary Report. J. Bone and Joint Surg., **29**: 1005–1018, Oct. 1947.

WHITMAN, ROYAL: Further Observations on Fracture of the Neck of the Femur in Childhood, with Special Reference to Its Diagnosis and to Its More Remote Results. Trans. Am. Orthop. Assn., **10**: 216–232, 1897.

DISCUSSION

DR. EDWIN F. CAVE, BOSTON, MASSACHUSETTS: Dr. Bosworth and his colleagues have brought forward a modification of another method of dealing with the ever present non-union, either alone or combined with disintegration of the femoral head, following fracture of the hip. They have applied the same operative technique to other less common conditions to correct deformity and relieve strain upon the upper end of the femur.

Any fracture which is followed by 25 to 30 per cent. of non-union or aseptic necrosis is not being satisfactorily managed, in spite of the great advance in the treatment of hip fractures since the development of the Smith-Petersen nail; prior to use of that nail, union resulted in from 50 to 60 per cent. only, and the mortality was very high. Most fractures will unite if they are properly reduced, securely held, and protected sufficiently long. Therefore, is not a considerable measure of our failures due to inadequate reduction of the fracture and inaccurate nailing? Too many surgeons ill-trained in joint surgery are nailing these fractures, accepting poor reductions, and giving improper follow-up care. You will note that, in Dr. Bosworth's series of twenty-two cases, only five were treated primarily by him. It is no wonder, therefore, that operations such as Dr. Bosworth proposes have become necessary. In our Fracture Clinic at the Massachusetts General Hospital, we are returning to more open reductions of femoral-neck fractures because a certain percentage cannot be reduced by closed manipulation, and at times portable roentgenograms lead us astray. We must first secure anatomical reductions and, second, proper introduction of the flanged nail.

We have had no experience with the type of operation that Dr. Bosworth proposes. In fact, in our Clinic we are reluctant to do any type of "McMurray osteotomy", with or without internal fixation, believing that, if it fails, we have burned our bridges in so far as any reconstruction procedure is concerned. We have, however, treated twenty cases of non-union with the nail and graft. The results were: five, excellent,—that is,

bony union, no limp, and no pain; seven, good,—that is, bony union with some limp and slight pain; seven, failures. One patient died before an end result could be determined.

A live femoral head is essential for the success of this procedure. If the head is dead, we prefer a cup arthroplasty, with or without downward transplantation of the trochanter or its muscle attachment, depending upon the length of the remaining portion of the femoral neck. In this group of cases, there were 117 old fractures of the femoral neck treated by arthroplasty. Of these, seventy-five operations were done for non-union, and forty-two for aseptic necrosis.

Recently an article appeared by King [a], of Melbourne, whose careful work in the operative treatment of hip fractures merits our consideration. He did the subtrochanteric osteotomy with internal fixation by means of a Smith-Petersen nail and Thornton plate as a primary procedure in fifty cases. Prior to this series, he had treated a group of 100 cases with simple nailing, and another 100 with nail and graft, and concluded:

"There is no significant improvement in the frequency of bone union of intracapsular fractures of the femoral neck by primary osteotomy—simple nailing, 69 per cent; nailing and bone grafting, 71 per cent; osteotomy, 72 per cent".

I congratulate the authors on originating an operative procedure which can be used in selected cases of deformity of the upper end of the femur. However, I should like to ask Dr. Bosworth if he believes that the dead femoral head is going to stand up under weight-bearing when it is placed upon the femoral shaft, or whether in time there will be increasing collapse, causing a recurrence of disability and hip pain.

[a] KING, THOMAS: A Critical Consideration of Primary Subtrochanteric Osteotomy and Internal Fixation for Recent Intracapsular Fractures of the Femoral Neck. Australian and New Zealand J. Surg., **19**: 177–197, 1950.

DR. PAUL C. COLONNA, PHILADELPHIA, PENNSYLVANIA: If there should have been any doubt that Dave Bosworth is an energetic and hard-working man, we certainly have had this dispelled today. This type of procedure consists in fracturing the bone to change the mechanics produced by the original deformity. In essence, it follows sound surgical principles for all fractures,—that is, first reducing the fracture; second, providing adequate bone contact, and third, immobilizing the limb. It is an effort to simplify the Dickson procedure, but it seems to me that in many ways the authors have gone about it the hard way.

I realize that this is a preliminary report and, therefore, a great many conditions have been included which will in time be eliminated, thus permitting us to get a true picture of the indications for this operation.

One would like to consider whether a frank pseudarthrosis of the hip can be corrected simply by changing the mechanics of the fracture. There are varying degrees of deformities and of aseptic necrosis with these non-unions. Can we treat non-union in other regions of the body by simple realignment, or is it not also necessary to freshen up the fracture surfaces and use bone grafts to hasten osteogenesis? I feel that this is a fundamental question; further work by Dr. Bosworth and others may help to answer it.

Another point which I get from this paper, particularly the remarks relating to non-union in fractures, is that the authors advise increasing the 60-degree angle which Dr. Dickson has recommended in his geometric osteotomy. This is a point which might bear careful consideration, and appears to be advisable in certain cases with coxa vara.

In those cases with fibrous union, I think the operation would be suitable, but in non-union with severe displacement I am not sure. I would certainly like to know more about those cases with displacement and aseptic necrosis, for in them I would feel very cautious about recommending the procedure. The authors indicate that this is a difficult procedure and I hope in the future they will define its indications more clearly.

Dr. Bosworth and his collaborators briefly consider aseptic necrosis. This is admittedly a problem for all of us. They indicate that, by changing the position of the head so that the direct weight thrust does not strike the aseptic area, one can expect revascularization and repair. This is a very interesting thought and one that we would like to see proved.

Of nine cases in which the procedure advocated was followed carefully—that is, osteotomy alone—four were unsatisfactory. Five were satisfactory, two of which, as stated, were treated too recently to make final conclusions. The five that were satisfactory represent 55.5 per cent., which is not a very high figure.

I have a direct difference of opinion regarding fractures of the neck of the femur in children from that expressed by the authors. I think it is a simple fracture to treat in the early acute stages. The complications which were brought out some years ago by John C. Wilson and others regarding late aseptic necrosis are, however, real problems. To subject a child of five years with an acute simple fracture to the rather formidable procedure advocated by the authors seems to me to entail a great deal of unnecessary work. The abduction method of Whitman is still a very satisfactory form of treatment in that early age group.

Dr. Bosworth has been very frank in collecting and showing us these cases and I have enjoyed his paper very much.

DR. M. N. SMITH-PETERSEN, BOSTON, MASSACHUSETTS: There are two points to be brought out from Dr. Bosworth's paper: First, as Dr. Colonna says, it is a frank and honest report, such as we always get from Dr. Bosworth. Second, it is a preliminary report. When a longer time has elapsed, the results will be less and

(*Continued on page 395*)

A DIAMOND-SHAPED GRAFT FROM THE ILIUM FOR NON-UNION OF THE TIBIA*

BY HARRY C. BLAIR, M.D., PORTLAND, OREGON

In the procedure here presented, a diamond-shaped graft from the ilium is used for non-union or delayed union of the tibia. To commend it are the ease of execution and the subsequent rapid healing. The method is based on the presumptions that fresh longitudinal fractures of long bones tend to heal quickly, that cancellous bone from the ilium is more osteogenetic than tibial cortex, and that pressure contact of a physiological nature aids in osteogenesis. Neither screw nor tie fixation is used.

TECHNIQUE

An incision is made over the fracture site. It should be long enough to expose the tibial fragments for a distance of three or four inches on either side of the non-union. If possible, the incision is made in an area that has not been scarred by previous injury or operation.

Any fibrous tissue found between the fractured ends of the tibia is removed. If dense, sclerotic, eburnated bone ends are present, they are also removed (Fig. 1, *A* and *B*). Each tibial fragment is then split longitudinally with an osteotome (Fig. 2, *A*). The splitting is continued for two, three, or four inches distally and proximally, depending on the distance of the fracture from the knee or ankle. The tendency is to sheer off to one side; to prevent this the splitting should be done slowly and with a wide, thin osteotome. Generally speaking, the thinner the osteotome, the greater the ease with which the splitting process is accomplished. No attempt is made to separate widely the fragments of the tibia.

It is important that the posterior periosteum be undivided by the osteotome, because its binding property will tend to hold the fragments together when the osteotome has been removed. Also, the periosteum and the muscles and fascia surrounding the bone will compress the split fragments and exert constant pressure on the graft when it has

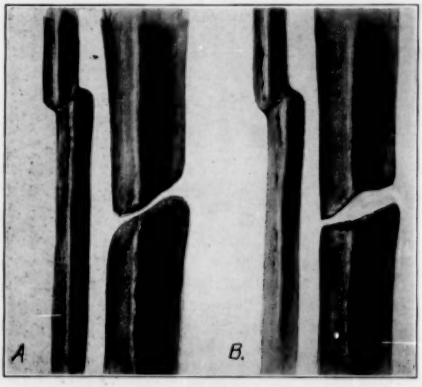


FIG. 1

Schematic drawing of (*A*) non-union of the tibia with eburnated ends and (*B*) bone ends freshened by removal of fibrous tissue.

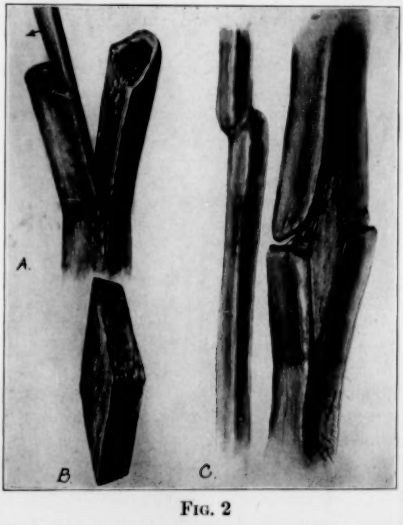


FIG. 2

Fig. 2: Schematic drawing showing: (*A*) technique of splitting bone, (*B*) diamond-shaped graft from ilium, (*C*) graft in place and additional small pieces of bone filling hiatus. The fibula is not refractured.

* Read at the Annual Meeting of The American Orthopaedic Association, Virginia Beach, Virginia, May 29, 1950.

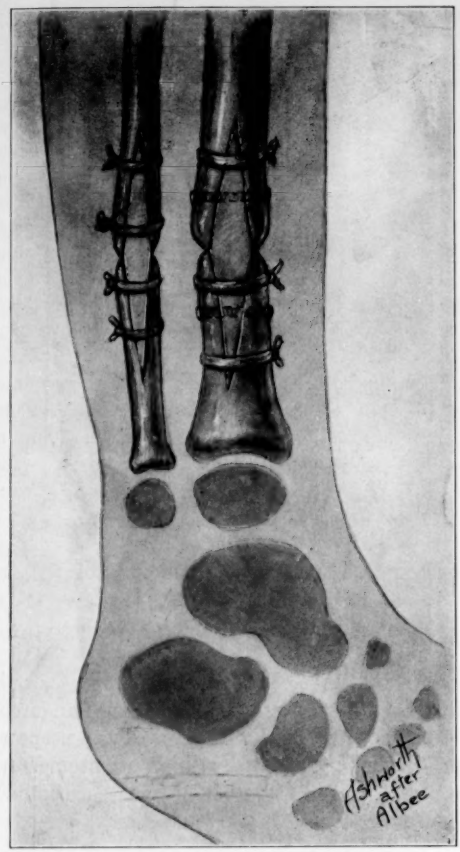


FIG. 3

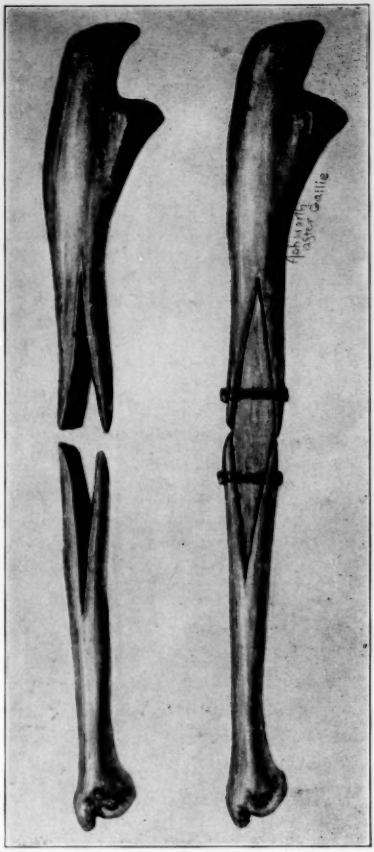


FIG. 4

Fig. 3: Albee's diamond-shaped bone graft with screw and kangaroo tendon fixation. (Adapted from Figure 71, Albee's *Orthopedic and Reconstruction Surgery, Industrial and Civilian*, and used by permission of W. B. Saunders Company.)

Fig. 4: Diamond-shaped bone graft with screw fixation as used by Gallie. (Adapted from Gallie's *The Transplantation of Bone*[8] and used by permission of the *British Medical Journal*.)

Fig. 5: Drawing showing tree graft (Albee's conception). The encircling rubber band simulates production of normal physiological pressure in man.

FIG. 5

been inserted and when the soft tissue has been sutured over it.

After the splitting has been completed, there is a fresh, long, linear fracture extending well into each tibial fragment. The splitting, as well as the removal of the fibrotic tissue between the bone ends, leaves a hiatus of varying extent, but roughly the shape of a diamond. To fill this space a diamond-shaped piece of bone is chiseled from the ilium (Fig. 2, *B*). The contour and size of this piece of bone should be such as to fill the gap snugly (Fig. 2, *C*). It is usually necessary to drive the graft into position with a large nail set. Additional small pieces of bone from the ilium may or may not be used to fill in the hiatus. Because the posterior periosteum tends to bind the fragmented bones together, there is little tendency for the graft to slip out of place. The anterior periosteum is closed if possible.

FIG. 6-A

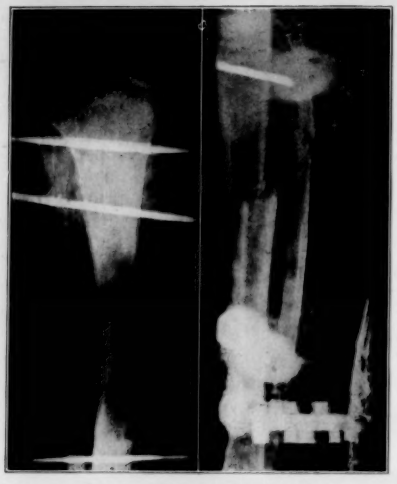


FIG. 6-B

Fig. 6-A: Case 1. Mr. A. J. Original fracture, April 17, 1946.
FIG. 6-B: Showing four-pin-distraction method of treatment.

If the fibula has been fractured, it is often united and should not be refractured. It helps to hold the graft snugly in place and to stabilize the tibia.

COMMENT

Diamond-shaped bone grafts were described by Albee (Fig. 3)[1], Gallie (Fig. 4), and perhaps others. Both Albee and Gallie used fixation devices of various kinds—kangaroo tendon, beef-bone pegs, and even screws and plates. Both used the motor saw to prepare the graft and its bed, although Gallie did split the apex of the bed with an osteotome.

Albee apparently reserved the diamond bone graft for the small bones, except in children. He believed like tissue should be placed together, that is, endosteum to endosteum, cambium layer to cambium layer. To illustrate his view, he cited the manner in

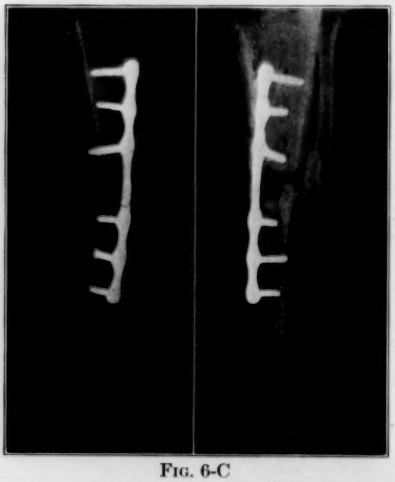


FIG. 6-C

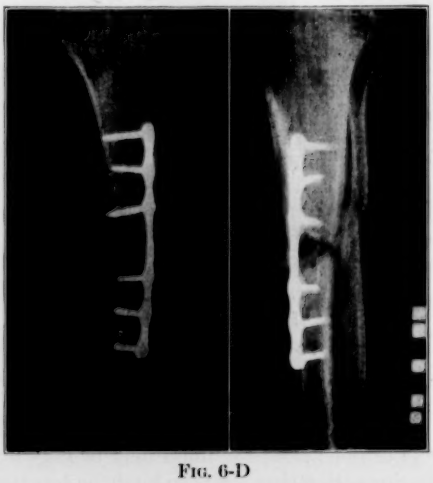


FIG. 6-D

Fig. 6-C: Failure of union is evident after plating with continued distraction, August 27, 1946.
Fig. 6-D: Infection and sequestration have occurred, October 5, 1946.

which the horticulturist grafts a tree (Fig. 5).[2]

Gallie, in 1931, reported he had used a diamond-shaped graft from the crest of the ilium for the radius, ulna, clavicle, fibula, and the smaller bones, cutting out a V-shaped piece from the end of each fracture fragment and splitting the end of the V with a thin osteotome; but he advised against the use of diamond-shaped grafts in the tibia, femur, and humerus. It was his belief that such grafts were not adequate for these bones and that some form of inlay, onlay, or medullary plugs must be used. He did not consider cancellous bone suitable for grafting the tibia because of the danger of fracturing the graft.

According to Gallie, the "commonest defect" was to neglect to fix the graft over a sufficient area. He declared it was futile to expect to overcome non-union by introducing a graft which only butts against a freshened fragment or rests on a bed only one-half inch long. He emphasized that immobilization was more important in bone-grafting than in fresh fractures.

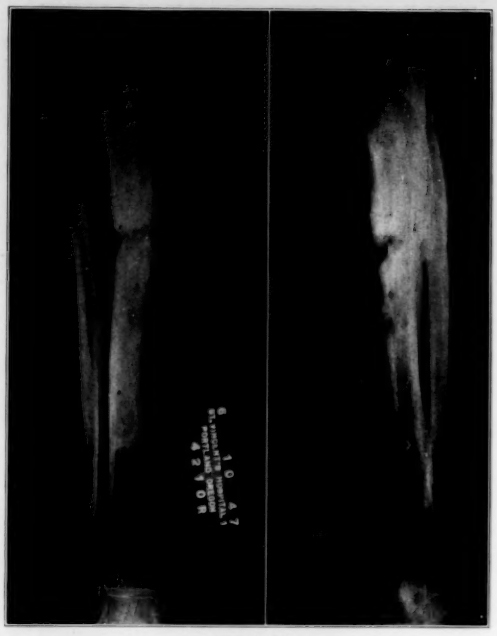


FIG. 6-E

June 10, 1947, after removal of plate and sequestrectomy.

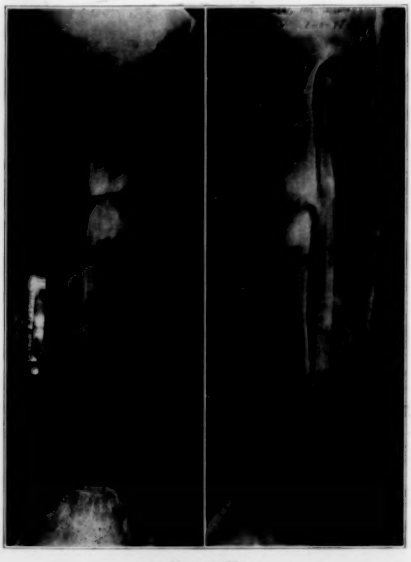


FIG. 6-F

FIG. 6-G

Fig. 6-F: January 11, 1949, showing diamond-shaped graft.
Fig. 6-G: April 24, 1950. The fracture has healed.

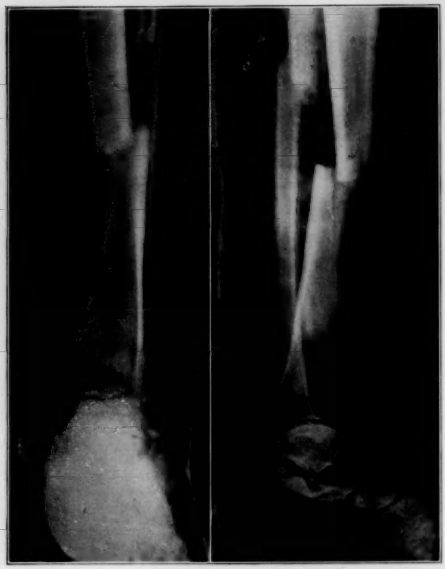


FIG. 7-A

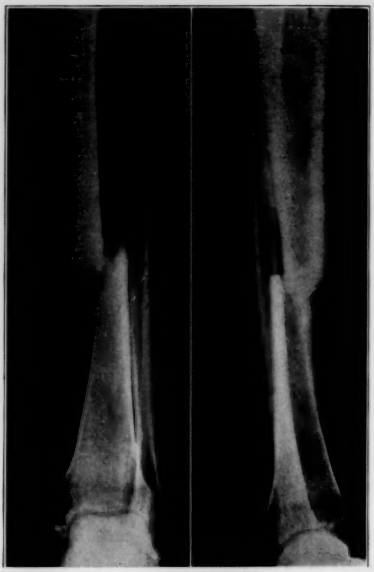


FIG. 7-B

Fig. 7-A: Case 2. Mr. F. H. Original fracture, April 1, 1949.
Fig. 7-B: August 15, 1949, showing delayed union with malposition.

FIG. 7-C

FIG. 7-D

Fig. 7-C: October 4, 1949, showing diamond-shaped bed cut with saw. Incorrect method.
Fig. 7-D: April 10, 1950, union in spite of incorrect technique.

FIG. 8-A

FIG. 8-B

FIG. 8-C
December 20, 1949. Showing solid union.

Fig. 8-A: Case 3. June 2, 1949. Non-union of two years' duration following plating.
Fig. 8-B: August 17, 1949. Plate has been removed and a diamond-shaped graft has been inserted.

FIG. 9-A

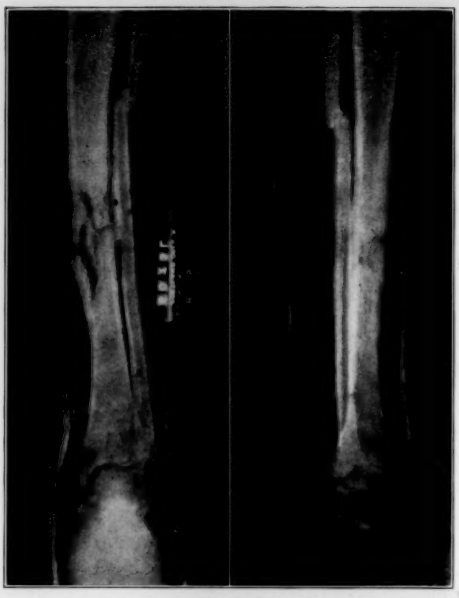


FIG. 9-B

For a number of years, Phemister [9, 10, 11] has stressed that fixation of the graft with metal is not necessary. He demonstrated excellent results in patients operated upon without screws or tie fixation for non-union of long bones. In the cases reported, he did not break down the fibrous union, except occasionally, and he used tibial bone as an onlay graft. It was his opinion that there were two common erroneous teachings,—namely, that the fracture line should be broken down, and that the graft should be firmly anchored to the fracture fragments by screws or encircling ties. Phemister exposed one side of the fractured bone, reflected the periosteum, leveled the bone if necessary, and depended entirely upon apposition and retention of the graft by suture of the periosteum and other soft parts. The donor site was usually the proximal portion of the involved tibia. Thus, only one incision was necessary.

FIG 9-C

Phemister, contrary to the views of Albee, asserted that it was not necessary to bring periosteal side to periosteal side or endosteum to endosteum to obtain bone repair. He explained

Fig. 9-A: Case 4. Mr. L. P. Non-union of fracture of the tibia, July 1, 1949.
Fig. 9-B: August 9, 1949, showing diamond-shaped bone graft.
Fig. 9-C: December 7, 1949. Solid union has resulted.

that once a bony bridge was established across a portion of the fracture line, the remaining intermediary callus would almost always ossify. Following the suggestions of this great teacher, many surgeons carried out the operation with success, which would indicate that theoretically and practically Phemister's criteria are sound. The muscles, periosteum, and fascia, tightly squeezed together when the wound is closed, act somewhat like a rubber band.

Eggers and his associates [6, 7], in their interesting experiments on rats, called attention to the influence of the contact-compression factor on osteogenesis. Using the membranous bones of the skulls of the animals, they varied the contact-compression factor. Their conclusions were: The contact-compression factor should incorporate compression forces in physiological muscle balance; contact compression favorably influences purposeful osteogenesis and fracture union; its absence fails to stimulate, but does not prevent osteogenesis; excessive pressure causes necrosis of the compressed bone; and, finally, the most advantageous compression force on the fracture surfaces is that exerted by the physiological forces of the musculature of the parts involved.

In discussing this paper, Compere emphasized two points: (1) "compression contact" creates the ideal situation for the most rapid healing of fractures and (2) the ideal compression forces are those created by the muscles themselves as they envelop the bones of the extremities.

Speaking particularly of positive pressure in arthrodesis of the knee joint, Charnley emphasized that continuous pressure tends to push the freshly cut edges together. He pointed out that, while the split edges apparently have a smooth appearance, they are only occasionally actually in contact. The most obvious effect of compression, he explained, is simple impaction of cancellous surfaces until the trabeculae almost interdigitate. Other effects are induction of dynamic forces, absorption, deposition, and formation of osteoid.

Charnley was of the opinion that, unless a continuous force kept the cut surfaces pushed together, movement would separate them and increase the possibility of fibrous-tissue growth. He stated that there is histological evidence that excessive movement of fragments predisposes to the formation of cartilage rather than bone. Slight movement, however, should not interfere with early bone formation because of the flexibility of osteoid tissue. On the other hand, plating of a fracture usually produces complete fixation and removes the stimulus for ossification.

Böhler cautioned that transplanted grafts should be treated with the utmost care. He cited the lesson to be "learned from gardeners and agriculturists, who in the grafting of trees lay the graft carefully into its bed, fasten it with cords, and never use screws, nails, or metal plates".

Some years ago the author used onlay grafts, placing the cortex of the graft to the cortex of the fractured bone and securing the graft with screws. Union took place quickly after this procedure.

In the procedure now described, neither screw nor tie fixation is used. To this extent it follows the dicta laid down by Phemister in 1947. It differs from Phemister's teaching, however, in that osteogenic bone from the ilium is used. Also, a linear fracture is made in each tibial fragment to form the bed for the diamond-shaped graft from the ilium. These have all the attributes of fresh fractures of the long bones sustained accidentally. Like other linear or oblique fractures of long bones, which seldom show delayed union, they heal quickly. Probably contributing to the rapid healing is the copious supply of fracture pabulum furnished by the exposure of large areas of newly fractured bone. Furthermore, the healing power of these, as well as of other fresh fractures, is greatest in the first few weeks following injury. When the subsequent contraction of the connective tissue begins and fibrosis takes place, the ability to form bone lessens.

REFERENCES

1. Albee, Fred H.: Bone-Graft Surgery, p. 191. Philadelphia, W. B. Saunders Co., 1915.

2. Albee, Fred H.: Orthopedic and Reconstruction Surgery, Industrial and Civilian, p. 147. Philadelphia, W. B. Saunders Co., 1919.
3. Böhler, Lorenz: The Treatment of Fractures. Ed. 4, English Edition, p. 104. Baltimore, William Wood and Co., 1935.
4. Charnley, John C.: Positive Pressure in Arthrodesis of the Knee Joint. J. Bone and Joint Surg., **30-B**: 478–486, Aug. 1948.
5. Compere, Edward L.: Discussion. J. Bone and Joint Surg., **31-A**: 716, Oct. 1949.
6. Eggers, G. W. N.: Internal Contact Splint. J. Bone and Joint Surg., **30-A**: 40–52, Jan. 1948.
7. Eggers, G. W. N.; Shindler, Thomas O., and Pomerat, Charles M.: The Influence of the Contact-Compression Factor on Osteogenesis in Surgical Fracture. J. Bone and Joint Surg., **31-A**: 693–716, Oct. 1949.
8. Gallie, W. E.: The Transplanation of Bone. British Med. J., **2**: 840–844, 1931.
9. Harkins, Henry N. and Phemister, Dallas B.: Simplified Technic of Onlay Grafts for all Ununited Fractures in Acceptable Position. J. Am. Med. Assn., **109**: 1501–1506, 1937.
10. Phemister, Dallas B.: Splint Grafts in the Treatment of Delayed and Nonunion of Fractures. Surg., Gynec., and Obstet., **52**: 376–381, 1931.
11. Phemister, Dallas B.: Treatment of Ununited Fractures by Onlay Bone Grafts without Screw or Tie Fixation and without Breaking Down of the Fibrous Union. J. Bone and Joint Surg., **29**: 946–960, Oct. 1947.

DISCUSSION

Edward L. Compere, M.D., Chicago, Illinois: In this day of widespread enthusiasm for the use of screws, plates, nails, wires (threaded and non-threaded), intramedullary pins (solid or tubulated), and various other gadgets for the internal fixation of fractures, it is gratifying to hear a paper which proposes an effective technique for the securing of a bone graft and the obtaining of union of ununited fractures of the long bones without the use of hardware.

Before reading this interesting paper, I could visualize but few advantages which the diamond-shaped graft could have over a graft shaped like a cigar, the old-fashioned rectangular graft, or any other bone graft. Dr. Blair has clearly established the merits of this diamond-shaped graft by the arguments set forth in his paper.

For about fifteen years, influenced by the teaching of Dr. Phemister, I have used with much satisfaction either onlay or inlay tibial bone grafts placed with the cancellous surface against the freshened cortex of the fracture fragments. The fibrous tissue between the fracture ends has not been removed, unless this has been necessary in order to restore length or alignment. I have not found it necessary to shorten the bone by resection of sclerotic fracture ends; drilling these ends has been adequate. If the onlay or inlay bone graft is wide, strong, and long enough to extend well beyond the fracture ends and make contact with healthy bone, it will unite and form a bridge for vascular tissue. The fibrous tissue will then ossify and the sclerotic ends of the fracture fragments will be replaced by creeping substitution. Whenever possible, I prefer to approach the fracture site through the scar of any previous operation rather than to make a separate incision and a closely adjacent parallel scar. Furthermore, although the iliac bone preferred by Dr. Blair is largely cancellous and hence is speedily replaced by living bone, there is not always negligible objection to the extra operation by which this graft is obtained. At least, when treating ununited fractures of the tibia, quite satisfactory bone with abundant cancellous tissue can be obtained from the proximal one-third of the tibia without a second incision. In fact, a very good diamond-shaped graft can be cut from the medial surface of the tibia just below the knee.

Dr. Blair has convinced me that there are advantages to the diamond-shaped graft and his method for using it, for: (1) The points of the diamond hold securely in the fracture fragments; (2) the split surfaces of the two fracture fragments provide wide areas of contact with fresh raw bone and, together with the surrounding soft tissues, maintain physiological compression forces between graft and fracture fragment and require no additional internal fixation; and (3) the thickest and strongest part of the diamond-shaped graft bridges the defect between the fracture ends.

I intend to try this diamond-shaped graft and the ingenious Blair method of fixing it in position. However, I shall continue to leave undisturbed as much of the fibrous tissue between the fracture fragments as possible and, in selected cases, especially for ununited fractures of the tibia, I shall obtain the diamond-shaped graft from the proximal portion of the same tibia.

I congratulate Dr. Blair upon this interesting and practical contribution to orthopaedic surgery and I appreciate the opportunity afforded me of discussing his paper.

J. Albert Key, M.D., St. Louis, Missouri: This operation evidently works well in Dr. Blair's hands. It is not easy to split and spring apart the shaft of the tibia, because this bone is apt to be brittle and the ends of the fragments may break off.

(*Continued on page 381*)

SLIPPING OF THE UPPER FEMORAL EPIPHYSIS
A Pathological Study

BY PIERRE LACROIX, M.D., LOUVAIN, BELGIUM, AND
JEAN VERBRUGGE, M.D., GHENT, BELGIUM

From the Department of Anatomy, University of Louvain, and the Department of Orthopaedic Surgery, University of Ghent

Opportunities for studying the pathology of coxa vara adolescentium have been few and reliable information is scanty. Current theories on the subject are based chiefly on interpretations of roentgenograms and are, therefore, numerous and conflicting. For these reasons we have deemed it useful to record as thoroughly as possible the pathological data which follow. As a matter of fact this investigation is, we believe, the only one based on the study of whole sections of the diseased area.

OBSERVATIONS

Case 1. A white boy with excessive weight and underdeveloped genitalia, was thirteen years of age when a diagnosis of incipient epiphysiolysis of the right hip was made. For reasons not clear to the writers, active treatment was not immediately instituted. Serial x-ray examinations showed the condition becoming steadily worse, until, three years after the onset of symptoms, a Whitman reconstruction operation was performed. The other hip remained uninvolved.

Roentgenographic and Histological Findings in Case 1

The anteroposterior roentgenogram, taken just before the operation, was compared with the frontal section of the specimen. (This should be the first step in all examinations to determine pathological changes.)

The region of the epiphyseal cartilage appears irregular and mottled on the roentgenogram (Fig. 1). The same region examined in the slide (Fig. 2) is wider at both the lateral and medial ends, where there appears to be fibrocartilaginous tissue, while in the central area this tissue is obliterated. Furthermore, this area is bordered by both compact and cancellous bone. The mottled appearance in the roentgenogram is thus easy to explain, since the roentgen rays must pass through tissues of various densities.

The roentgenogram shows that the upper portion of the neck is angulated (the medial slope of this angle being indicated by an arrow) and there is a groove, also shown by an arrow, on the lower aspect of the neck. The shadow of the head as a whole has taken the form of a crescent with sharply pointed ends.

The following are the detailed microscopic findings:

Region of the Epiphyseal Cartilage

In its upper portion (upper rectangle in Fig. 2, and Fig. 3), the epiphyseal cartilage is replaced by cartilaginous and fibrous tissues. The fibrous tissue (left portion of Fig. 3) is vascularized by winding capillaries.

The boundary between this fibrocartilaginous tissue and the adjoining bone tissue appears clearly defined when examined in ordinary light, but looks somewhat different when studied in polarized light. Figures 4 and 5 are photomicrographs of the same area, the first taken with normal monochromatic light, the second with polarized light. The latter shows that the fibrils of the cartilaginous tissue are sealed in the bone, a structure analogous to that of a tendon attachment.

In the central portion of the region (central rectangle in Fig. 2, shown enlarged in Fig. 6) there is an empty space between the epiphyseal and the metaphyseal bone. Small

FIG. 1

FIG. 2

Fig. 1: Slipping of upper femoral epiphysis in a sixteen-year-old boy. The roentgenogram was taken just before the resection, three years after onset of symptoms. The specimen has been analyzed histologically (Figs. 2 to 13). The upper arrow points to the region illustrated by Fig. 10, the lower to the groove a section of which is shown in Fig. 11.

Fig. 2: Frontal section (× 2.3) of the specimen removed surgically to demonstrate general relationship with the roentgenogram. The three regions outlined by rectangles are shown more highly magnified in Figs. 3, 6, and 7.

remnants of fibrous and of cartilaginous tissue are found on the walls of this space. There is nothing to suggest the formation of callus or of a pseudarthrosis. It seems, therefore, that this central region in a previous phase of development resembled the upper region, but that its cartilaginous tissue has been destroyed, leaving an empty space.

During growth an epiphysis is normally attached to the shaft by the growth cartilage and by the periosteum. In coxa vara adolescentium the growth cartilage is replaced by a

FIG. 3

Region of the upper rectangle in Fig. 2 (× 16). Epiphyseal trabeculae are seen in the upper portion of the figure, metaphyseal trabeculae in the lower portion. The epiphyseal cartilage is replaced by tissue which is partly fibrous and partly cartilaginous.

FIG. 4

FIG. 5

Fig. 4: Section (× 52) showing border between cartilaginous tissue and adjoining bone as seen by normal light.

Fig. 5: Section (× 52) showing same region as in Fig. 4, but photographed by polarized light. The fibrillar continuity between the cartilaginous tissue and the adjoining bone is now obvious.

tissue which, in spite of its fibrillar continuity with the bone, is obviously weaker than the normal tissue. In some places this tissue disappears. On such a basis, it is easy to under-

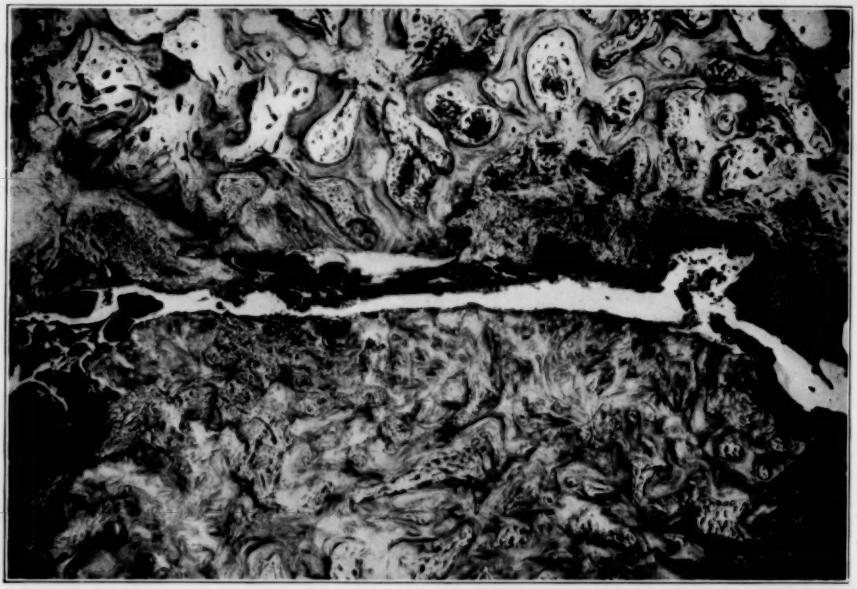


FIG. 6

Region of the central rectangle of Fig. 2 (× 16). Epiphyseal trabeculae are seen in the upper portion of the figure, metaphyseal trabeculae in the lower portion. The epiphyseal cartilage has disappeared, leaving an empty space.

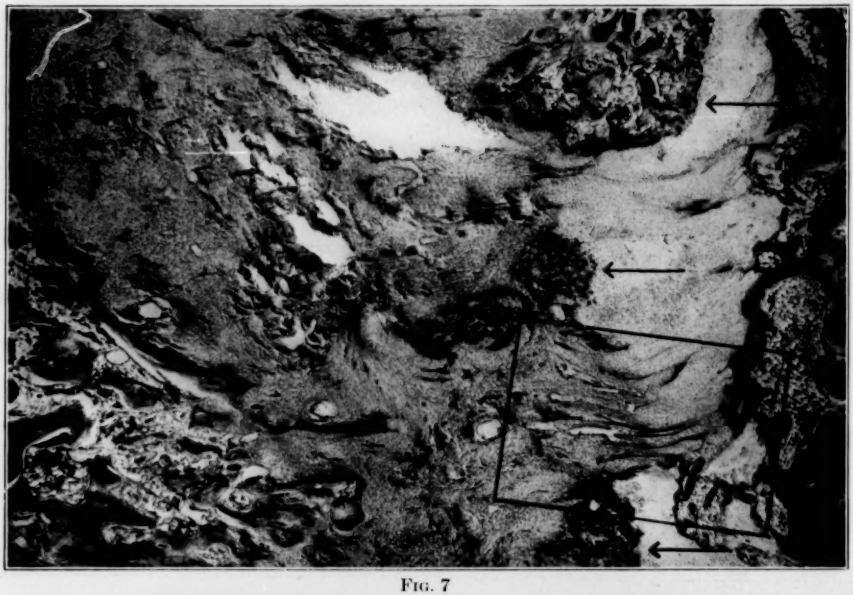


FIG. 7

Region of the lower rectangle of Fig. 2 (× 16). To the right, the epiphyseal trabeculae; to the left, the metaphyseal trabeculae. The three arrows point to three nodules of endochondral bone. The region outlined by a rectangle is shown at a higher magnification in Fig. 8.

stand how muscle pull and weight-bearing give rise to the characteristic deformity.

A more careful study of the lesions will enable us to go further into the analysis of the pathological events.

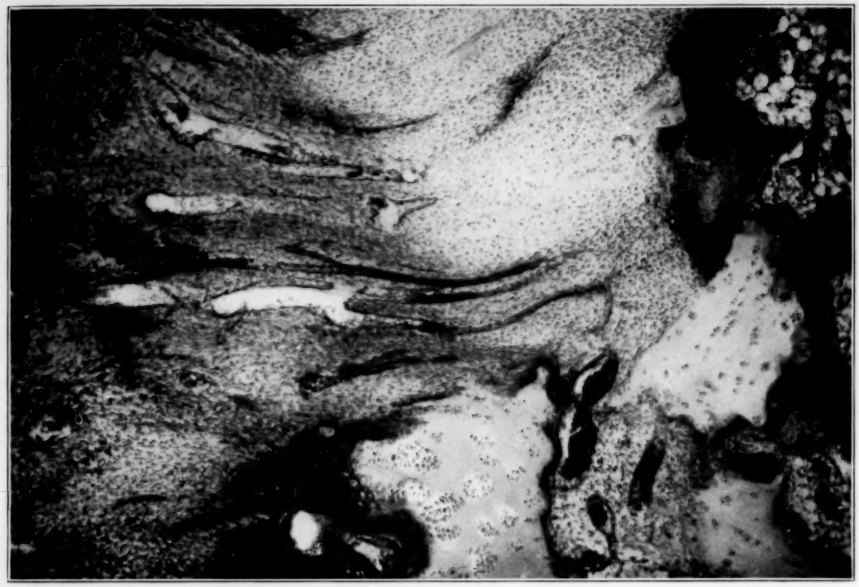


FIG. 8

Region outlined by rectangle in Fig. 7 (× 48). From right to left, the cartilaginous tissue is seen gradually being transformed into fibrous tissue.

FIG. 9

A typical illustration of the process shown in Fig. 8. From right to left, axial proliferation of cartilage cells, followed by transformation of the cartilage into fibrous tissue (× 66).

In the lower portion of the epiphyseal-cartilage region (lower rectangle of Fig. 2, and Fig. 7), three nodules of endochondral ossification (shown by arrows) are enclosed between a thin layer of cartilaginous tissue to the right and a thick layer of fibrous tissue

FIG. 10

Section (× 55) of the upper portion of the femoral neck (upper arrow in Fig. 1). The surface of the neck is being actively eroded. Arrows point to osteoclasts.

FIG. 11

Section (× 41) of the groove indicated by the lower arrow in Fig. 1. The periosteum has become thickened. The groove is being filled by trabeculae of new bone. Arrows point to osteoblasts.

FIG. 12

FIG. 13

Fig. 12: Structure of the trabeculae inside the femoral neck taken by normal light (× 27). The mosaic structure apparent here can be seen more clearly in Fig. 13.
Fig. 13: Same region as in Fig. 12, but photographed by polarized instead of normal light (× 27).

to the left. The cartilaginous tissue between these nodules is being transformed gradually into fibrous tissue. Figure 8, a section of the same area shown at a higher magnification, illustrates the gradual transformation of the one tissue into the other.

Still another instance of the same basic process is shown in Figure 9, a section taken from the same specimen. In the right portion of the figure, the cells are proliferating and forming axial groups. Up to this stage their behavior is fairly normal, but their ultimate fate is quite abnormal. Instead of becoming hypertrophied, dying, and initiating the formation of endochondral trabeculae, they retain their size, remain alive, and finally take part in the formation of a dense fibrous tissue which is invaded by capillaries.

It may be pointed out that the presence of the small nodules of endochondral ossification in Figure 7 shows that the process illustrated in Figure 9 is by no means irreversible. Since the nodules are isolated from the metaphysis by fibrous tissue, the growth cartilage which is now producing them is the very cartilage which, in a previous stage, produced the fibrous tissue. This recovery is limited to such small areas that it cannot possibly alter the evolution of the disease as a whole. Nevertheless, these sporadic reversals of the process of ossification help to explain the variety of lesions encountered in the same slide.

Region of the Neck

On the roentgenogram (Fig. 1) the neck appears angulated. It seems that, as the head slipped down, it pulled the adjoining portion of the neck down with it. Three regions have been chosen to illustrate the histological processes underlying this deformity.

Figure 10 is a section of the upper aspect of the neck (upper arrow of Fig. 1). There is no cortex. The trabeculae are being absorbed wherever they are in contact with the periosteum. Numerous osteoclasts are good evidence of this active absorption. It may be safely concluded that the angulation shown in the upper aspect of the neck is the result of erosion of bone.

The microscopic appearance is quite different in the groove of the lower aspect of the neck. In fact, here the process is reversed. Figure 11, a section of this groove, shows a thickened periosteum producing narrow trabeculae of new bone. Osteoblasts are clustered around the growing trabeculae.

FIG. 14

Case 2. Slipping of the upper femoral epiphysis in a sixteen-year-old boy. The only remnants of the growth cartilage are a few areas of fibrous tissue like the one illustrated here (× 13).

FIG. 15

The fibrous tissue is being slowly ossified from the periphery toward the center (× 132).

FIG. 16

Although bony union has occurred between the head and the neck, a small nodule of endochondral ossification (arrow) has developed in the fibrous tissue (× 14).

Inside the neck, an active remodeling of the bone is everywhere apparent. Any one of the trabeculae might have produced the results shown in Figures 12 and 13. The first of these is taken by normal light, the second by polarized light; one is the complement of the other and both show a mosaic structure, a "*Breccienbau*", more elaborate than normally. Nowhere is there any sign of an osteoid seam.

The interrelation between these various observations appears very clear. Slipping downward, the head pulls down the periosteum, which is stretched against the upper rim of the neck, and at the same time is loosened from the lower aspect. The consequences follow automatically. Bone is absorbed on the upper surface, and new bone is laid down on the lower surface. This is the mechanism by which one of us has tried to explain the migration of the pedicled exostoses observed in children with multiple exostoses [7,8].

As for the remodeling of the trabeculae, it is due to the gradual shifting of the stresses transmitted by the neck. A changing distribution of the stresses is always followed by an internal rearrangement of the trabeculae, and the mosaic structure is the histological expression of this phenomenon.

To put it briefly, the statement that the femoral neck bends downward and tends to follow the displacement of the head is purely a descriptive one and should not be taken literally. It expresses the result of the pathological process, not its mechanism.

Our analysis in this study concerns the displacement in the frontal plane, the only one which can be observed in our sections. It is probable that similar lesions explain the displacement observed roentgenographically in the horizontal plane.

Region of the Head

Signs of remodeling are found in the head. They are accounted for by its faulty position. In every slide where the ligamentum teres can be seen, it contains patent and competent blood vessels, an observation also made by Kleinberg and Friedman.

CASE 2: Our second case was similar to the first in respect to sex, age, presence of an adiposogenital syndrome, unilateral involvement, duration of symptoms, and treatment.

Histological Findings in Case 2

Although the clinical history in this case is similar to that of the first, the lesions have reached a more advanced stage. In some places, the head is united with the neck; in others, the epiphyseal cartilage is replaced by nodules of fibrous tissue completely enclosed in a thin bony shell (Fig. 14). The nodules are being slowly ossified from the periphery toward the center (Fig. 15).

Even at this end stage, a last sign of the normal process may be observed. Figure 16 shows a rather unusual condition,—a small nest of endochondral ossification in the fibrous tissue. Similar regeneration nests are found in the epiphyseal cartilage where growth has been temporarily stopped by large doses of x-rays.

DISCUSSION

The sequence of events which lead to the characteristic deformity is obvious. The primary cause lies in the epiphyseal cartilage, which, instead of producing endochondral bone, is transformed into fibrous tissue. All the other lesions are secondary.

The word "dyschondroplasia" would summarize the description. The word is etymologically sound, but it should be avoided since it is now synonymous with Ollier's disease.

Howorth obtained from his biopsy material some findings which coincide with ours. On the other hand, the description of Sutro is rather at variance. This author has examined tissues removed surgically from three patients. He says that "the condition is one of fracture through the upper femoral epiphyseal plate and the contiguous trabeculae of bone". He could not see any "definite evidence of primary degeneration of the epiphysial plate".* More work is therefore needed. However, we feel entitled to discuss the subject on the basis of our illustrations, which leave little room for doubt.

The most striking feature of the disease remains its association in a number of cases with excessive weight (nineteen out of twenty-six in Green's series [3]), and underdeveloped genitalia,—that is, with the adiposogenital syndrome. This has often led to the belief that the skeletal lesion is due to some endocrine disturbance linked with puberty.

In connection with this theory, Harris has shown that growth hormone decreases, whereas sex hormone increases, the shearing strength of the upper epiphyseal plate of the tibia in the rat. We doubt that these findings, interesting as they are, can be considered to have enough significance to explain the disease, because the alterations found in the epiphyseal plate of the rat bear no resemblance at all to the pathological changes observed in man. It must therefore be stressed that, so far, the endocrine theory has nothing else to support it than a mere clinical suggestion.

Many other theories have been put forward. Let us examine them briefly. They will at least teach us how misleading the roentgenographic appearance can be unless it is substantiated by observation of the pathological changes.

In the past, trauma was often accused of causing this condition and is still held responsible by some authors. Our own findings correspond with those in most of the known case histories: trauma may reveal the disease or may complicate it by causing an acute slipping, but it cannot be a primary cause of the lesion.

A weakening of the periosteum, a low-grade infection, circulatory disturbances, late rickets, or a localized osteomalacia,—all these hypotheses still have their proponents even

* Burckhardt [3] studied biopsies from three cases of coxa vara infantum. His findings are quoted here because they lead to interesting comparisons. He sees in "partial bone necrosis and secondary destruction of cartilage due to ingrowing connective tissue" the main features of the morbid anatomy. The writers believe, therefore, that, as far as pathology is concerned, the cases of coxa vara observed in young children should not be put in the same category with those observed in adolescents.

in contemporary papers. Yet all are definitely ruled out by observation of the pathological conditions.

An association between coxa vara adolescentium and renal rickets has been described by Brailsford. His illustrations seem convincing and it must be admitted that renal rickets may, in some cases, lead to a lesion of the upper femoral cartilage and thus cause slipping of the head. But the similarity is only roentgenographic and does not imply a real kinship between the two diseases. The pathology of renal rickets is well known and has nothing in common with that of coxa vara adolescentium.

CONCLUSION

The pathology of the slipping of the upper femoral epiphysis has been studied on whole sections of the diseased area. Histological evidence goes to show that the basic pathological change associated with the deformity takes place in the epiphyseal cartilage, which, instead of producing endochondral bone, is transformed into fibrous tissue. All the lesions observed in the neck and in the head are secondary.

NOTE: The slides of the sections studied were skillfully prepared by the late Dr. H. Scherer, Head of the Department of Pathology at the Bunge Institute, Antwerp, Belgium.

REFERENCES

1. BRAILSFORD, J. F.: The Radiology of Bones and Joints. Ed. 4. London, J. and A. Churchill Ltd., 1948.
2. BURCKHARDT, E.: Zur Klinik und pathologischen Anatomie der Coxa vara infantum. Helvetica Chir. Acta, **13:** 28–61, 1946.
3. GREEN, W. T.: Slipping of the Upper Femoral Epiphysis. Arch. Surg., **50:** 19–33, 1945.
4. HARRIS, W. R.: The Endocrine Basis for Slipping of the Upper Femoral Epiphysis. J. Bone and Joint Surg., **32-B:** 5–11, Feb. 1950.
5. HOWORTH, M. B.: Slipping of the Upper Femoral Epiphysis. J. Bone and Joint Surg., **31-A:** 734–747, Oct. 1949.
6. KLEINBERG, SAMUEL, and FRIEDMAN, ELIOT: Observations on the Vascularity of the Ligamentum Teres. Bull. Hosp. for Joint Dis., **1:** 72–76, 1940.
7. LACROIX, PIERRE: L'organisation des os. Liège, Editions Desoer, and Paris, Masson et Cie, 1949.
8. LACROIX, PIERRE: Contribution à l'étude de la maladie exostosante. Sur la migration des exostoses au cours de la croissance. Rev. d'Orthop., **36:** 20–25, 1950.
9. SUTRO, C. J.: Slipping of the Capital Epiphysis of the Femur in Adolescence. Arch. Surg., **31:** 345–360, 1935.

DISCUSSION

DIAMOND-SHAPED GRAFT FOR NON-UNION OF THE TIBIA

(Continued from page 370)

I think that Melvin Henderson introduced the diamond-shaped graft for bridging gaps in bone, and I have used it according to his method by which the massive diamond-shaped grafts, cut a little longer than the gap, were sprung into the medullary canals. Thus the graft and both fragments were firmly immobilized and pressed together and I think that this is the chief reason for their success.

I prefer the onlay graft either with or without fixation. Unless there is a bone defect I would be inclined to use a free onlay graft of the Phemister type.

JOHN R. MOORE, M.D., PHILADELPHIA, PENNSYLVANIA: Dr. Blair has not submitted a sufficiently large number of cases to justify his contentions. The follow-up on those cases presented is not sufficiently long to warrant the use of a diamond-shaped graft. The principle, however, is sound; it is not new.

FRACTURES OF THE ANTERIOR PROCESS OF THE CALCANEUS *

BY MOSES GELLMAN, M.D., BALTIMORE, MARYLAND

According to the latest edition of a comprehensive textbook on fractures, the os calcis is broken more frequently than any of the other tarsal bones[6]. The mere mention of the word "fracture" as applied to the calcaneus brings to mind the image of a bone with its structure and shape grossly disrupted and its articular relationships seriously disorganized. There then follow the arduous and complicated efforts attendant upon a satisfactory and stable reduction of all the displaced elements, the prolonged period of immobilization, the tedious stages of functional restoration, resulting in a foot with varying degrees of permanent disability. It is, therefore, pleasant to be able to state that an isolated fracture of the anterior process of the os calcis presents no such disturbing problems

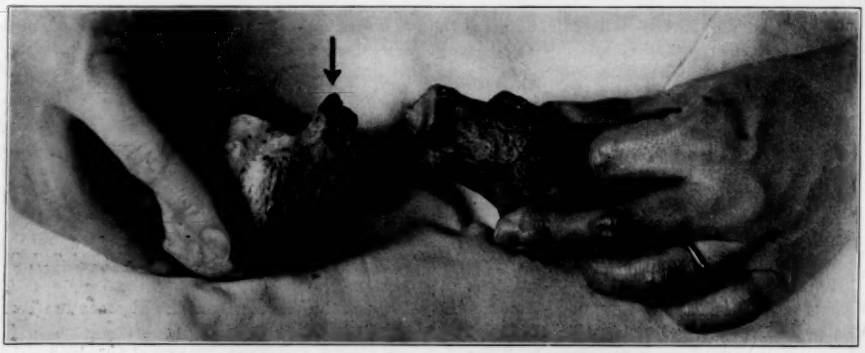


FIG. 1-A FIG. 1-B

Fig. 1-A: Photograph demonstrating the forward extremity of the calcaneus, its articulating cuboidal surface, and the triangular beak-like anterior process (arrow), from which the extensor digitorum brevis muscle originates (shaded).

Fig. 1-B: The other os calcis has a poorly developed anterior process, because the floor of the sinus tarsi is flat.

either to the physician or to his patient. It is a trivial condition, a glorified sprain-fracture, and the problem it presents is one of diagnosis rather than of treatment.

There is no lack of classifications of fractures of the heel bone. Key and Conwell refer to that of Conn. Watson-Jones, acknowledging his indebtedness to Vidal (as quoted by Böhler), and to Jaekle and Clark for separating the various types, brings a characteristic orderliness into his own classification, which is commendably clear and detailed, but makes no mention of the specific break which is the subject of this paper. The literature on fractures of the anterior process of the os calcis is not abundant. The sparsity of reported cases may be due to the fact that this type of fracture is relatively rare, or is frequently overlooked.

The largest series of this particular fracture thus far encountered is that of Dachtler, who, in May 1931, reported twenty-six cases seen over a period of eleven years. With one exception they were of industrial origin. With two exceptions they were caused in the same manner by a particular type of hand-truck, which struck the subjects from behind in the neighborhood of the calf. This injury caused strong dorsiflexion of the foot on the ankle; the resultant compression of the lateral anterior-superior portion of the os calcis by the adjacent cuboid bone produced the fracture. Christopher thought that this condition had

* Read at the Clinical Day Session of the Annual Meeting of The American Orthopaedic Association, Baltimore, Maryland, May 22, 1950.

not been previously described when he reported three cases in October 1931, but hastened to correct this impression by acknowledging Dachtler's priority. Christopher felt that the fracture was probably caused by forcible plantar flexion of the foot.

Von Braunbehrens, who recorded four cases in 1935, believed that the splitting off of a fragment from the top of the anterior joint area of the calcaneus was caused by a shearing action exerted on this portion of the bone as it rotated under traumatic conditions against the cuboid bone. Speed in 1942 described this condition as a "minute fracture of the anterior edge of the calcaneus at first unrecognized and only demonstrated after repeated roentgenograms in an effort to explain painful disability". Magnuson and Stack writing in 1949 regarded the fracture as avulsive in type, occurring usually in women, due to a strain mechanism in which the fore part of the foot was strongly adducted, with the force applied while the foot was in the equinus position. In the same year, King discussed three cases of painful spastic flat-foot due to a "sprain" several months before the first examination. These patients appeared to have had a sudden traumatic abduction of the fore part of the foot, with resultant compression fractures of the superior cuboidal articular surface of the calcaneus. It is possible that King's fractures may also have disturbed other important adjacent structures, thereby contributing to the persistent spasticity. The patients in this present series uniformly described their injury as consisting of a "twist", but were not always certain of the precise direction of the force which had caused the fracture. The majority thought they had turned the foot inward. Since all were women, they were probably wearing high-heeled shoes; hence an element of plantar flexion may well have been added to the adduction.

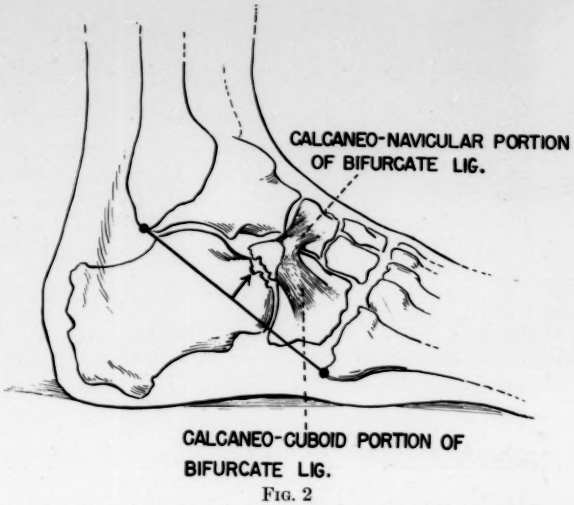


FIG. 2

Schematic drawing demonstrating how the bifurcate ligament can play a part in avulsing the anterior process of the calcaneus. If a line drawn from the tip of the external malleolus to the tip of the base of the fifth metatarsal bone (usually a distance of three inches) is bisected by a perpendicular line projected towards the top of the tarsus, the point of maximum tenderness will be found.

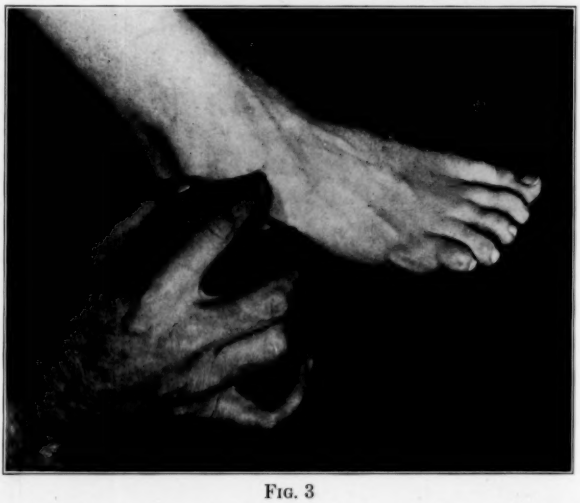


FIG. 3

If the examiner places his thumb on the tip of the external malleolus and the middle finger on the tip of the base of the fifth metatarsal bone, the slightly crooked index finger held equidistant between these two bones will fall directly upon an exquisitely tender point.

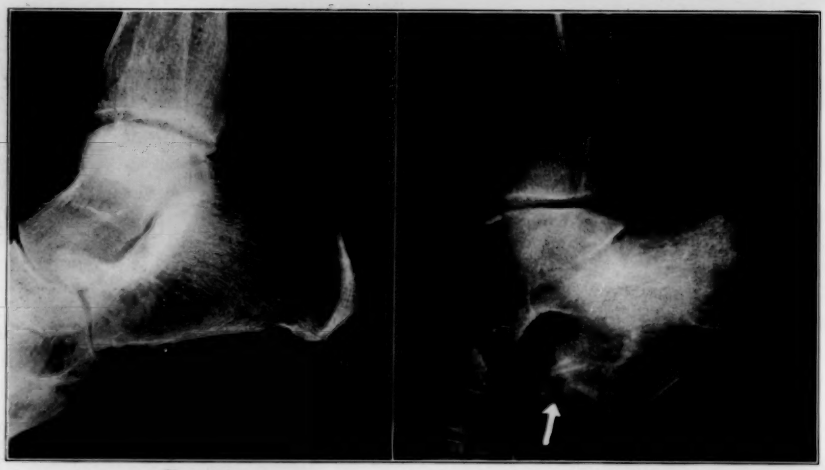


FIG. 4-A FIG. 4-B

Fig. 4-A: Routine direct lateral view of the foot. The fracture line here is barely evident, and might easily be missed.

Fig. 4-B: Oblique view. The arrow indicates the fracture line, which is clearly seen from this angle.

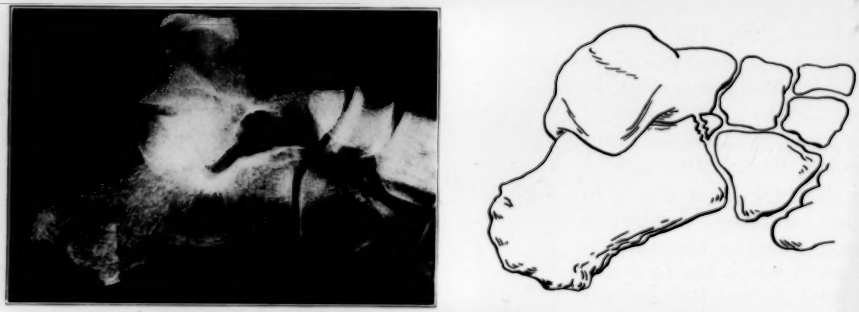


FIG. 5-A FIG. 5-B

Fig. 5-A: Note how a good oblique view of the foot clearly separates the shadow of the anterior process of the calcaneus from that of the front and under surfaces of the talus.

Fig. 5-B: The artist has been too realistic in portraying the fracture line, which was nearly missed in the roentgenogram.

The anterior extremity of the os calcis is furnished with a saddle-shaped surface in its forward aspect for articulation with the cuboid bone. Its inner third broadens out as the sustentaculum tali. The outer two thirds make up the floor of the sinus tarsi, do not come into contact with the under surface of the talus, and form no part of the talocalcaneal joint. The forward edges of the bone are sharply defined, except medially, and serve for the attachment of ligaments. The dorsal surface of the lateral side of this anterior extremity is rough and raised, and from this projection, the anterior process (Fig. 1-A, arrow), originates the extensor digitorum brevis muscle. Attached to this same point is the bifurcate ligament, which consists of a calcaneonavicular and a calcaneocuboid portion.

Examination of several calcaneal specimens has revealed that in some instances the floor of the sinus tarsi is rather flat; hence, the anterior process is poorly developed (Fig. 1-B). When the lateral half of the floor rises sharply upward, there is produced a well-defined triangular beak (Fig. 1-A, arrow) which would seem to be more vulnerable to the effects of a traumatic force, whether it be avulsive, compressive, or torsional. Since the

bifurcate ligament is attached to this process, sudden adduction of the fore part of the foot at the lateral mediotarsal joint, especially in equinus, would exert strong tension upon the bone and so tear it away (Fig. 2). While this is regarded as the most common manner in which these fractures occur, it is admitted that force exerted in other ways upon the same place may cause a similar type of fracture.

The writer became interested in this type of fracture in December 1946, when he encountered the first case dealt with in this series. This was followed by a second case within a few weeks, in January 1947, and by two more in November and December of 1948. Observations on two additional cases, one seen in September 1949, the other in February 1950, were communicated to the author by Dr. Edwin O. Geckeler of Philadelphia, and bring the total in this series up to six. The patients were all women, from thirty-two to fifty-nine years of age. Four of the fractures involved the right foot.

FIG. 6

An excellent demonstration of a fracture of the anterior process of the calcaneus. (Dr. Geckeler's case.)

The following is a composite picture of the typical features. Following a sudden twist, there is immediate pain on the outer aspect of the mid portion of the foot and considerable discomfort on weight-bearing. Tenderness is localized to an area nearly one-half inch in diameter on the dorsal surface of the calcaneocuboid joint, which is found about one and one-half inches forward and slightly below the tip of the external malleolus. Manipulation, especially in adduction, is resisted by pain and spasm. Discoloration is seen later. The swelling, at first present over a limited area, becomes more widespread; the tissues grow puffy and tend to obscure the involved structures. The point of maximum tenderness can be sharply identified (Figs. 2 and 3), and this point, especially its location, represents by far the most significant single diagnostic feature.

The symptoms and signs just described do not necessarily mean that a fracture is actually present, but they should certainly arouse a strong suspicion that one may be dealing with a bone lesion. Actually the diagnosis of fracture of the anterior calcaneal process is made much more often than can be confirmed by roentgenograms. Ligamentous strains and sprains are the commonest lesions found in this area. Sprain-fractures elsewhere on the lateral aspect of the os calcis, and fractures of the cuboid bone, alone or with involvement of the calcaneus, will also be discovered.

Of paramount importance are properly taken and accurately read roentgenograms. The routine anteroposterior view of the foot is seldom helpful. A direct lateral exposure is not always sufficient to demonstrate this fracture, especially if the fracture line throws only a faint shadow, or if there is no appreciable displacement of the fragment. Oblique views at several different angles must be made in order to separate the shadow of the anterior process of the os calcis from that of the front and under surfaces of the talus (Figs. 4-A and 4-B). The use of a magnifying glass is strongly recommended for the examination of the roentgenograms, and the entire calcaneocuboid area should be subjected to careful scrutiny. Unless suspected and scrupulously sought, minute fractures at this site are often unseen and remain undiagnosed; hence they are improperly handled (Figs. 5-A and 5-B).

With the discovery of the fracture, appropriate treatment should be instituted. Gross displacement may be corrected by manipulation. A simple below-the-knee cast gives comfort in the more severe cases; an elastic bandage is sufficient in the less severe cases. No weight-bearing is permitted for four weeks, when physical therapy is begun. The disability is likely to last longer than anticipated; accordingly, it is prudent to warn patients at the outset that their convalescence will be slow. The final outcome, however, will generally be regarded as satisfactory. In the four personal cases in this group the period of treatment and observation was thirteen, seventeen, seventeen, and six and one-half weeks respectively — an average of thirteen weeks. None of the patients was completely well at the time of discharge, and each had some mild residual discomfort and swelling, though not enough to warrant further therapy.

SUMMARY

It is believed that fractures of the anterior process of the calcaneus are relatively rare or are frequently overlooked. The manner in which this fracture is sustained may vary, but the cause is commonly believed to be forcible adduction of the fore part of the foot, combined with plantar flexion. The precise location of a trigger point aids in the diagnosis, which must be confirmed by careful roentgenographic observations. While the disability is prolonged, the prognosis is good. It is hoped that this discussion will stimulate an awareness of the condition.

REFERENCES

1. von Braunbehrens, H.: Abbruch an der Facies articularis anterior calcanei, ein Beitrag zur Mechanik der Fersenbeinbrüche. Deutsche Zeit. f. Chir., **245**: 359–370, 1935.
2. Christopher, Frederick: Fracture of the Anterior Process of the Calcaneus. J. Bone and Joint Surg., **13**: 877–879, Oct. 1931.
3. Dachtler, H. W.: Fractures of the Anterior Superior Portion of the Os Calcis Due to Indirect Violence. Am. J. Roentgenol., **25**: 629–631, 1931.
4. Geckeler, E. O.: Personal communications.
5. Jaekle, R. F., and Clark, A. G.: Fractures of the Os Calcis. Surg., Gynec., and Obstet., **64**: 663–672, 1937.
6. Key, J. A., and Conwell, H. E.: The Management of Fractures, Dislocations, and Sprains. Ed. 4. St. Louis, C. V. Mosby Co., 1946.
7. King, Don: Correspondence Club Letter, Sept. 22, 1949.
8. Magnuson, P. B., and Stack, J. K.: Fractures. Ed. 5. Philadelphia, J. B. Lippincott Co., 1949.
9. Speed, Kellogg: Textbook of Fractures and Dislocations. Ed. 4. Philadelphia, Lea and Febiger, 1942.
10. Watson-Jones, Reginald: Fractures and Joint Injuries. Ed. 3. Baltimore, Williams and Wilkins, 1946.

FRACTURES OF THE NECK OF THE FEMUR IN CHILDREN

A Clinical Study

BY GUILLERMO ALLENDE, M.D., AND LUIS G. LEZAMA, M.D., CÓRDOBA, ARGENTINA

Fractures of the neck of the femur are rare among children when one considers the frequency with which they occur among adults. For example, in the General Hospital of Los Angeles, only two were found in children, compared with 600 such fractures in adults[8].

The complications and prognosis vary according to the type of fracture. Some general

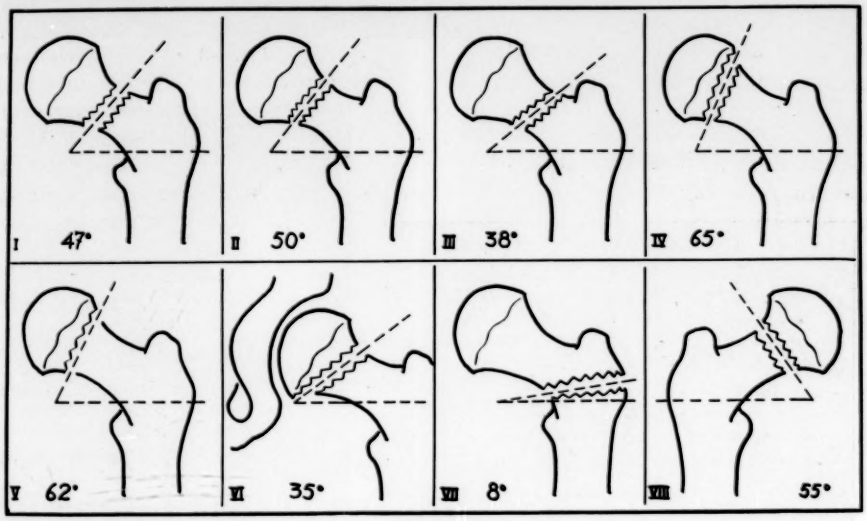


FIG. 1

Fig. 1: Variation of the fracture-line angle in the eight cases. In Cases 4, 5, and 8, in which the angle was greater than 50 degrees, surgical treatment was necessary.

Fig. 2: Showing the operation performed in Case 8; an osteotomy was supplemented by a fibular graft. Shaded section shows area of necrosis.

surgeons who may have had very little actual experience in children's orthopaedics report straightforward treatment and favorable results, while many surgeons with a great deal of experience think that this fracture is far more serious in a child than in an adult.

The two essential factors with which the surgeon must be concerned are the obliquity of the fracture line, and the possible appearance of aseptic necrosis.

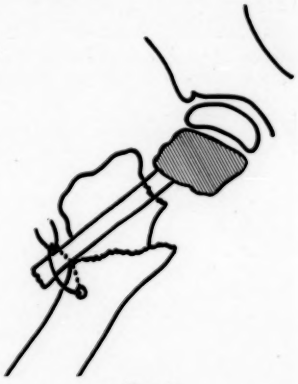


FIG. 2

The writers have had under their care eight children with fractures of the neck of the femur, the youngest patient being three years old and the oldest fourteen. Each of the fractures was the result of severe trauma, and some of them were associated with other fractures,—fracture of the pelvis (Case 6), fracture of the humerus (Case 7), and fracture of the skull (Case 8).

* Read at the First River Plata Congress of Traumatology and Orthopaedic Surgery, Rosario, Argentina, November 21, 1949.

FIG. 3-A

FIG. 3-B

FIG. 3-C

FIG. 3-D

FIG. 3-E

FIG. 3-F

Case 4. A boy, eight years old, arrived three days after the accident, with mid-cervical fracture of the neck of the left femur.

Figs. 3-A and 3-B: Roentgenograms made June 14,

(*Continued on page 389*)

(Figs. 3-A and 3-B, *continued*)

1947 show condition on admission. The fracture was reduced and plaster applied on July 24, 1947. Consolidation progressed slowly.

Fig. 3-C: Roentgenogram, December 1, 1947, showing non-union. Aseptic necrosis of the neck had developed, and the femur was in varus.

Fig. 3-D: After a subtrochanteric osteotomy, performed on April 18, 1948. The fracture united, but on May 3, 1948 there was a new fracture of the femoral diaphysis (supracondylar) in the same site; this was treated with fixation and plaster.

Figs. 3-E and 3-F: Roentgenograms made June 28, 1948, two years after the accident. There is coxa vara and shortening of one inch.

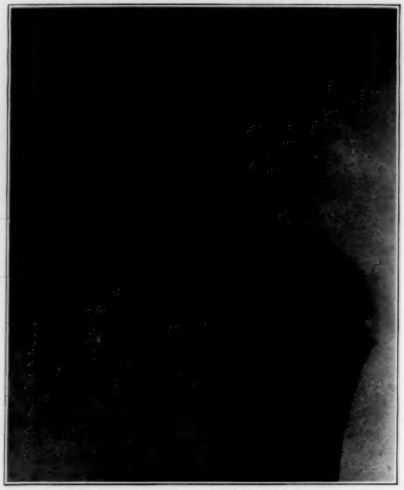


FIG. 4-A

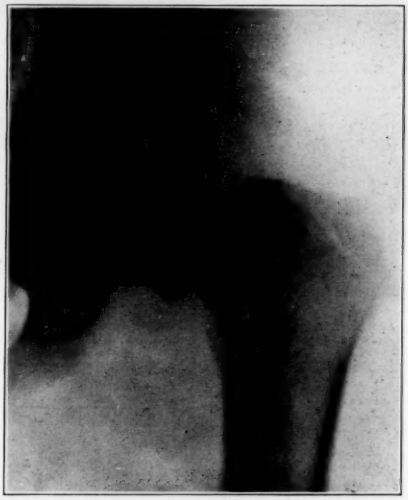


FIG. 4-B

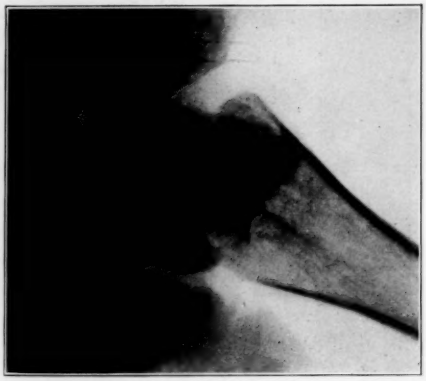


FIG. 4-C

FIG. 4-D

Case 5. A boy, seven years old, arrived September 10, 1947, forty days after the fracture. He had been treated with plaster. He presented a pseudarthrosis in a mid-cervical fracture of the left femoral neck.

Fig. 4-A: Roentgenogram October 1, 1947, showing fracture ununited. Plaster fixation had been used.

Figs. 4-B and 4-C: Roentgenograms made on November 10, 1947 showed pseudarthrosis. Operation was advised.

Fig. 4-D: November 10, 1947: Roentgenogram made after osteotomy, combined with a fibular graft, had been performed. The extremity was kept in plaster until March 20, 1948, when consolidation in varus was found.

There was one instance of epiphysiolysis, five mid-cervical fractures, one cervico-

FIG. 4-E

August 25, 1948. After the graft and osteotomy, there was limited flexion, internal rotation, and abduction.

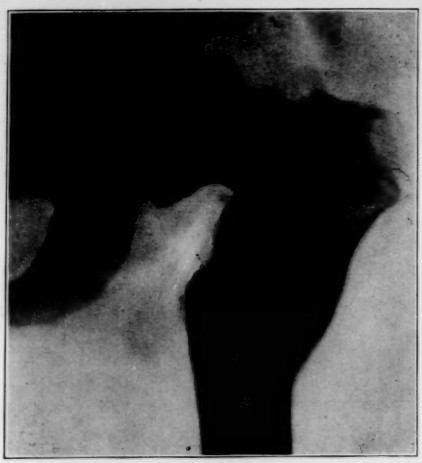


FIG. 4-F

FIG. 4-G

trochanteric, and one intertrochanteric fracture. The type of fracture most frequently encountered was the mid-cervical, although other writers [1] have found the fractures to be in the cervicotrochanteric region in 75 per cent. of their cases. In one of our cases there was no displacement, but in the other seven displacement was evident.

Direction of the Fracture Line

One of the most important factors to be taken into consideration immediately after the fracture has been reduced is the direction of the fracture

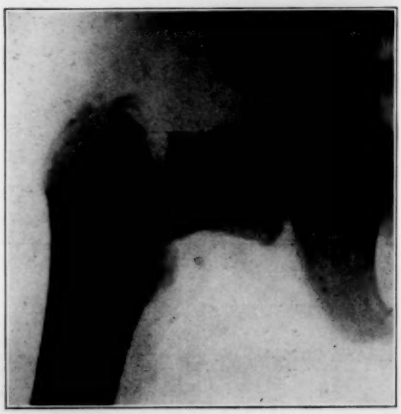


FIG. 5-A

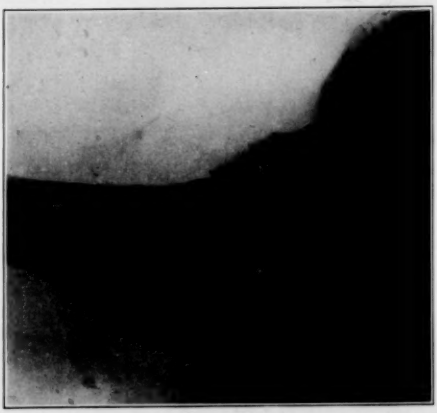


FIG. 5-B

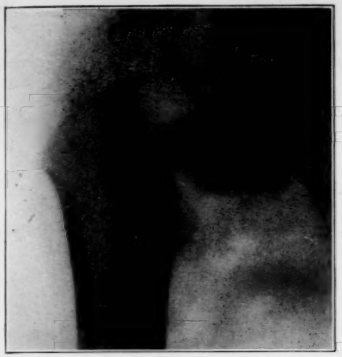


FIG. 5-C

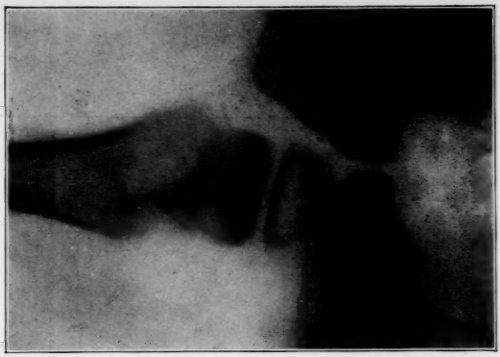


FIG. 5-D

Case 8. A boy, aged three, arrived fifty days after the accident, with a mid-cervical fracture of the right femoral neck. He had been treated with plaster. Aseptic necrosis had developed.

Figs. 5-A and 5-B: Roentgenograms January 20, 1948 showing injury.

Figs. 5-C and 5-D: Roentgenograms March 14, 1948 showing aseptic necrosis of the femoral neck. An osteotomy, combined with a bone graft, was done.

FIG. 5-E

FIG. 5-F

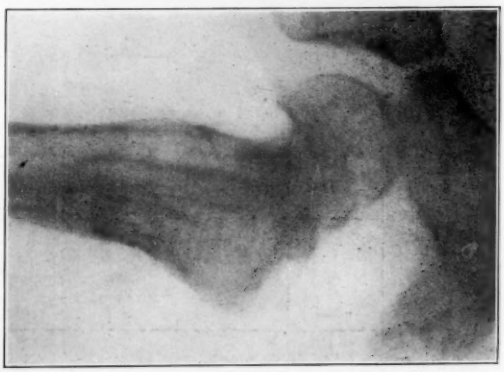


FIG. 5-G

Figs. 5-E, 5-F, and 5-G: June 29, 1948, three months after the operation, when plaster fixation was removed, the fracture had united.

line, or the plane of the fracture, because it is impossible to measure this exactly before reduction. In five of our cases (Table I) the Pauwels angle was less than 50 degrees, and these patients responded well to orthopaedic treatment, following reduction by the Whitman technique. But in the three cases where the angle of inclination of the fracture line was greater than 50 degrees, surgical intervention was indicated (Fig. 1).

TABLE I

TYPE OF FRACTURE, TREATMENT, AND END RESULT

Case No.	Sex	Age	Date of Fracture	Date of First Treatment	Type of Fracture	Type of Treatment	Reduction Obtained	Complications	Secondary Procedure	Date of Last Treatment	End Result
1	F.	11	Sept. 25, 1935	Sept. 25, 1935	Mid-cervical, left hip; angle 47 degrees, varus	Plaster and traction	Yes	None		Aug. 1936	Good
2	F.	10	Feb. 17, 1940	Feb. 21, 1940	Mid-cervical, left hip; undisplaced; angle 48 degrees	Plaster		None		Apr. 1947	Good
3	F.	14	Aug. 2, 1944	Aug. 28, 1944	Cervicotrochanteric, left hip; angle 38 degrees, varus	Plaster	Yes	None		Dec. 1948	Good, 100 degrees varus
4	M.	8	June 11, 1947	June 14, 1947	Mid-cervical, left hip; angle 65 degrees, varus	Plaster	Yes	Aseptic necrosis; pseudarthrosis	Osteotomy	June 1949	Poor, coxa vara
5	M.	7	Aug. 1, 1947	Spet. 10, 1947	Mid-cervical, left hip, angle 62 degrees, varus	Plaster	Poor	Pseudarthrosis	Graft, osteotomy	Aug. 1948	Poor, coxa vara
6	M.	5	Oct. 1, 1948	Oct. 5, 1948	Epiphysiolysis, left hip; angle 35 degrees	Plaster both legs	Yes	Fracture of pelvis		Dec. 1948	Unknown
7	M.	11	Jan. 22, 1949	Feb. 3, 1949	Intertrochanteric, left hip; angle 8 degrees, varus	Plaster	Yes	Fracture of right humerus		May 1949	Good
8	M.	3	Jan. 17, 1949	Jan. 22, 1949	Mid-cervical, right hip; angle 55 degrees, varus	Plaster	Poor	Aseptic necrosis of the neck	Graft, osteotomy	Sept. 1949	Good

Figs. 5-H, 5-I, and 5-J: September 1, 1949, twenty months after the operation, the child was walking with leg in 15 degrees of internal rotation. External rotation was limited to 5 degrees. The other movements were normal.

FIG. 5-H

Aseptic Necrosis

Aseptic necrosis is a frequent complication. Carrell and Carrell found it in 33 per cent. of their cases. Many authors,—as, for example, Johanssen, zur Verth, and Nielsen, have published reports of their cases in which this complication was a factor. Garcia Castellanos presented one case at *La Sociedad de Cirugia de Córdoba* in 1947.

The frequency of this sequela is due, in great part, to the condition of the vessels supplying the neck of the femur [2, 8]. In children the metaphysis and the center of ossification are supplied principally by the retinacular vessels, which are exposed to injury, especially in case of a fracture at the base of the femoral neck. The foveolar artery does not exist in 20 per cent. of the cases,[8] and in the remainder it supplies only the cartilage near the small fossa of the ligamentum teres without reaching the ossification center of the head. This center of ossification does not reach full development until the child is between eleven and thirteen years old, at which time the foveolar arteries become anastomosed with the retinacular arteries. After this has occurred, there is a greater possibility

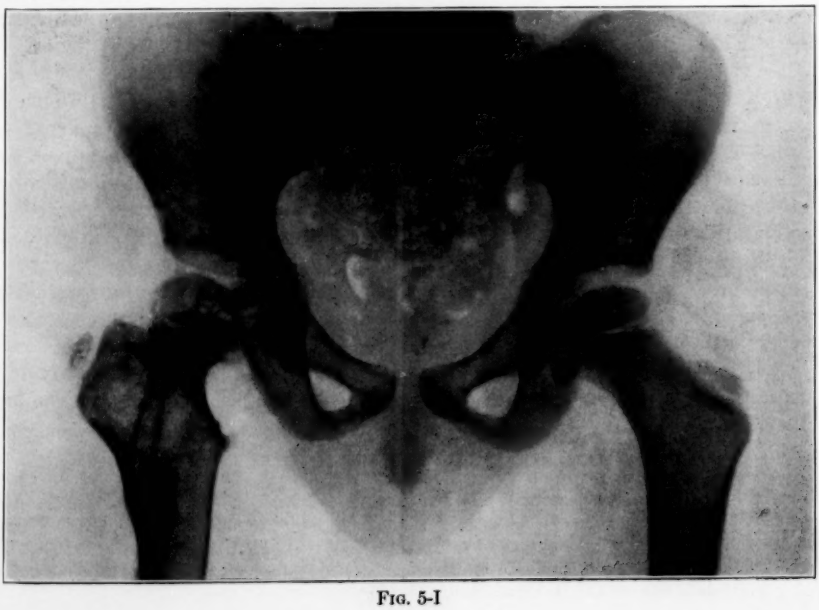


FIG. 5-I

FIG. 5-J

that together these vessels will supply the necessary circulation to the fractured neck. It is this developmental background of blood supply which accounts for the greater frequency of aseptic necrosis in children than in adults.

This complication occurred in only two of our eight cases (Table I). In one (Case 4), the necrosis took place in the extremity of the fractured fragments (Fig. 3-C). In the other (Case 8) necrosis occurred in the metaphysis of the femur, between the fracture line and the growing cartilage (Figs. 5-C and 5-D), leaving the epiphysis safe. Thus, in the latter case, although the patient was only three years old, the foveolar artery was sufficient to supply the entire epiphysis.

DISCUSSION

In those cases where the angle of inclination was less than 50 degrees, we found that reduction under general anaesthesia and immobilization for two months in the Whitman position constituted the treatment of choice.

When the Pauwels angle was greater than 50 degrees and the displacement was not too great, an intertrochanteric osteotomy modifying the direction of the fracture line was sufficient to obtain consolidation, although the final result was nearly always a coxa vara (Case 4). We found that, when displacement was pronounced and the fracture was not a recent one, it was better to use a fibular graft with an intertrochanteric osteotomy. This graft, when introduced into the fragments of the metaphysis, produces a lever movement which raises the head and prevents varus of the neck (Fig. 2), according to the method described by Mayer.

Carrell advised that in cases "seen late in coxa vara position (after four weeks) [the fracture] should be permitted to unite" and then the deformity should be corrected by osteotomy; otherwise aseptic necrosis may supervene. We feel that, when the Pauwels angle is greater than 50 degrees, a prompt osteotomy is fundamental to solid bony union. The process of consolidation can be accelerated by the use of a fibular graft combined with the osteotomy.

REFERENCES

1. CARRELL, BRANDON, and CARRELL, W. B.: Fractures in the Neck of the Femur in Children. With Particular Reference to Aseptic Necrosis. J. Bone and Joint Surg., **23**: 225–239, Apr. 1941.
2. FRACASSI, H.: Circulación arterial de los huesos largos. La Prensa Méd. Argentina, **28**: 371–393, 1941.
3. GARCIA CASTELLANOS, J.: Necrosis de la cabeza femoral post-traumática. Presentación de un caso. Bol. y Trab. de la Soc. de Cir. de Córdoba, **8**: 143–146, 1947.

4. JOHANSSEN, SVEN: Über Epiphyssennekrose bei geheilten Collumfrakturen. Zentralbl. f. Chir., **54**: 2214–2222, 1927.
5. LOGROSCINO, DOMENICO: La tuberculosi del collo del femore. Chir. d. Org. di Movemento, **19**: 295–320, 1934.
6. MAYER, LEO: The Treatment of Coxa Vara of Severe Grade. Bull. Hosp. Joint Dis., **8**: 3–14, 1947.
7. NIELSEN, B.: Calvé-Perthes' Disease after Fracture of Neck of Femur in Young Persons and Its Significance for Understanding the Pathogenesis of Aseptic Necroses of Epiphyses. Hospitalstidende, **81**: 773–788, 1938.
8. TUCKER, F. R.: Arterial Supply to the Femoral Head and Its Importance. J. Bone and Joint Surg., **31B**: 82–93, Feb., 1949.
9. WILSON, J. C.: Fractures of the Neck of the Femur in Childhood. J. Bone and Joint Surg., **22**: 531–546, July, 1940.
10. ZUR VERTH, MAX: Sekundäre Nekrose des Schenkelkopfes nach Schenkelhalsbrüchen Jugendlicher. Zentralbl. f. Chir., **62**: 2549–2557, 1935.

DISCUSSION

SUBTROCHANTERIC OSTEOTOMY AND SPLINE FIXATION

(*Continued from page 361*)

less encouraging; they aren't too encouraging now. I have seen cases like those favorably reported in this paper eventually show disastrous results. When you do an osteotomy in the region of the upper end of the femur—and I don't care particularly what kind of osteotomy is done—a new mechanical relationship is created, but a faulty joint is left. This doesn't solve the problem, just temporizes with it. Temporarily the weight-bearing line is improved and pain is diminished. Sooner or later pain is bound to recur, and the combination of a faulty joint and the mechanical condition created by the osteotomy presents a problem which is extremely difficult, sometimes even impossible, to solve.

DR. JAMES A. DICKSON, CLEVELAND, OHIO: I am very much interested in Dr. Bosworth's presentation, particularly so as he said this work was stimulated by a paper that I gave before this organization four years ago. He has attempted to simplify the procedure, but I fear in so doing he has lost sight of a most important principle in the treatment of ununited fractures, namely the use of a bone graft. He has corrected the mechanical errors that contributed to the development of non-union, but has relied entirely on impaction of the fragments to procure a union. I am convinced that this is not sufficient for the best results.

In my presentation I outlined a method of accurately controlling the degree of rotation and explained how a bone graft could be used in this procedure. The problem, as I see it, in the treatment of ununited fractures of the femoral neck is to rotate the head sufficiently to re-establish its normal relationship with the acetabulum, and at the same time to bring the fracture line into a healing position; this is in accordance with the principles set forth by Pauwels and Linton. The amount of rotation necessary may be 45 degrees or 60 degrees, depending on the varus position of the head. If the head of the bone is lying in its normal position (so that there is practically no varus) a 60-degree rotation will almost certainly result in dislocation. It would be similar to rotating your own hip 60 degrees. You are sure to get into trouble by forcing too much abduction. At the present time I find that I am using the 45-degree rotation much more frequently than the 60-degree method.

I cannot over-emphasize the importance of the graft. We all recognize how essential this is in the treatment of non-unions elsewhere in the body. Dr. Thompson has just shown us the advantages of the bone graft in delayed union of the femur.

In order to procure the best results in this difficult problem we must recognize the development of a non-union at the earliest possible stage. Early recognition, before aseptic necrosis has developed, and correction of the faulty mechanical factors by osteotomy and the use of a bone graft will greatly improve our results. In the later cases with atrophic changes in the head, an adequate graft is of even greater importance in preventing further aseptic necrosis.

(*Continued on page 420*)

EXPERIMENTAL INFARCTION OF BONE AND BONE MARROW

Sequelae of Severance of the Nutrient Artery and Stripping of Periosteum *

BY LEE N. FOSTER, M.D., ROBERT P. KELLY, JR., M.D., AND WALTER M. WATTS, JR., M.D.,
CHAMBLEE, GEORGIA

From the Departments of Pathology and Orthopaedic Surgery of the Emory University School of Medicine, Emory University, Georgia, and the Laboratory Service and Section of Orthopaedic Surgery of Lawson Veterans Administration Hospital, Chamblee

The diseases of bone which appear to stem from interference with its blood supply include aseptic necrosis of the femoral head, necrosis of the central fragment following fracture of the carpal navicular, and infarcts of long bones and other bones. Such lesions have been described from the study of surgical and autopsy material, and in general these data are adequate for the development of clinical-pathological correlations and sound pathogenetic interpretation [9,10,17–19]. In spite of voluminous clinical material, there is little experimental work to elucidate the mechanism of injury and repair of infarcted bones.

The greater number of studies in this field have been catalogued in the papers of Kistler and of Bragdon, Foster, and Sosman. Consequently, only the most significant publications need be considered here.

Axhausen stated that Wollenberg was the first to produce infarction of bone experimentally. Wollenberg injected talc into the femoral arteries of dogs, which was followed by the appearance of areas of necrosis in the metaphysis and epiphysis. In a comparable experiment, Bergmann injected silver suspended in gum arabic. Although he found no changes in the epiphysis, necrotic foci were irregularly distributed in the bone cortex. The areas of necrosis could reasonably be the result of obstruction of blood flow. Later, Brunschwig reported no changes following the cutting of the femoral nutrient artery and the stripping of the periosteum from bone in adult dogs except in one animal of his series, where a cyst was found in the medullary cavity. Recently, Kistler observed the development of infarcts in the femora of rabbits following the injection of particulate carbon into the femoral artery. His series was large enough to permit study of many of the sequelae of infarcts occurring in bone. The first successful attempt to produce infarction by simple ligation was described by Huggins and Wiege, who found that marrow infarction followed interruption of the femoral nutrient artery in the rabbit.

Johnson described a variety of injuries subsequent to cutting the periosteal and nutrient blood supply of the femur. This study emphasized the effect of these changes on the healing and reorganization of bone transplants. Other experiments regarding the effect of interruption of the vascular supply to bone on the healing of injured bone have been published by Haldeman and by Kolodny. Although such experiments are analogous to those presented in this paper, they cannot be applied directly to the problems to be discussed.

The works of Kistler, Bergmann, and Wollenberg show that interference with the vascular supply in small vessels of cortical bone may result in death of bone, and that attempts at repair in and about infarcted areas may stimulate the production of bone. Injection of particulate matter, so finely divided that it is able to enter the nutrient vessels, is followed by necrosis of the marrow and sometimes by bone formation within the

* Sponsored by the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are a result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

FIG. 1

Photomicrograph (× 110) of cortical bone of rapidly growing rabbit, twenty-four hours after stripping of periosteum and severance of nutrient artery. The osteocytes still stain. The inset (× 300) shows thrombi of neutrophils within Haversian vessels. Hematoxylin and eosin stain.

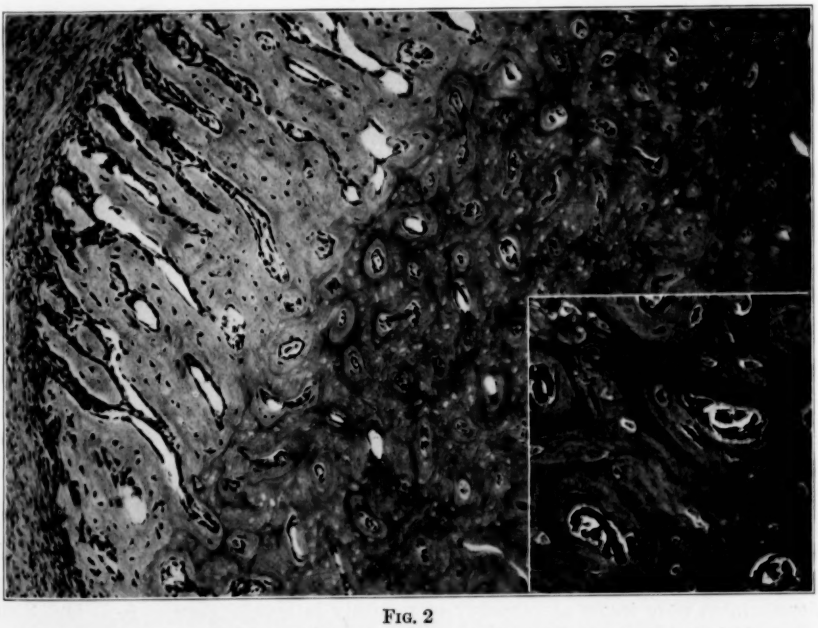


FIG. 2

Photomicrograph (× 110) of cortical bone of rapidly growing rabbit, seventy-two hours following procedure. New bone is being developed from the fascial envelope of the femur. Inset (× 300) from junction of old and new cortex shows osteocyte lacunae containing osteocytes that have undergone coagulation necrosis. Cylinders of viable bone with crisply stained osteocytes have already invaded the dead tissue. Hematoxylin and eosin stain.

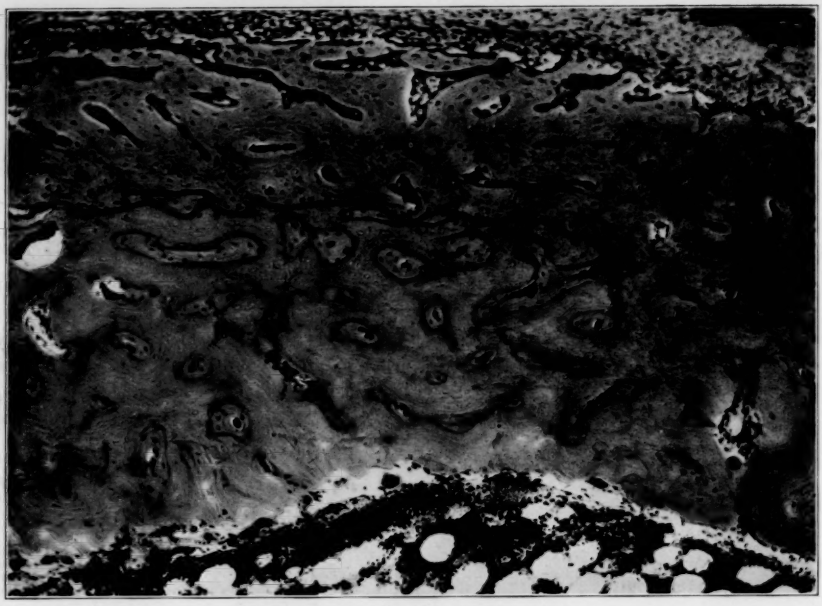


FIG. 3

Photomicrograph (× 110) of cortical bone of rapidly growing rabbit, three weeks following procedure. A heavy shell of new cortex is present. Partial replacement of dead bone has occurred. Endosteal ossification is noted, as well as osteoclastic resorption of dead bone. The cortical infarct overlies a segment of viable marrow. Hematoxylin and eosin stain.

marrow space. Lack of definite patterns of infarction makes description of the changes which follow these experimental procedures difficult, because lesions which characterize certain phases of this process do not invariably appear. The records of the existing data seem to be conflicting, as shown when the results reported by Brunschwig are compared with those of the other investigators. Injection methods do not allow the pattern of infarction to be well controlled. For this reason, a relationship between the nature of blood supply and the resultant changes in bone cannot be demonstrated.

Consequently, an attempt was made to develop a method by which the results produced were constant and the sequences of injury could be closely followed. In an earlier experiment [2], pathological changes in the structure of bone, subsequent to cutting the nutrient artery and vein, were traced.

MATERIALS AND METHODS

Eighteen small, rapidly growing rabbits were used in the first group. In these animals, active enchondral-bone formation was seen at the time of autopsy. The animals were anaesthetized with ether and, under sterile precautions, the nutrient vessels of the left femur were exposed and severed; the periosteum was cleanly stripped from the subtrochanteric level to the reflection of the synovial membrane of the knee joint. The more prominent fascial planes and the skin were closed with silk sutures and the wound was covered with celloidin. The right femur was used as a control. Following surgery, serial roentgenograms were taken at biweekly or monthly intervals. Figures 6, 7, and 8 show the characteristic histological appearance of the epiphyses of these animals; roentgenograms of their femora are shown in Figures 4-A, 4-B, 5-A, and 5-B.

The animals were killed with chloroform at intervals of from twenty-four hours to five months after operation. The right and left femora of each rabbit were removed, as

well as a portion of the surrounding soft tissue. The bones were cut longitudinally through each epiphysis and transversely across the shaft into fragments, 1.5 to 2.0 centimeters in length. They were fixed in Zenker's fluid, decalcified in nitric acid, embedded in celloidin,

FIG. 4-A

FIG. 4-B

Fig. 4-A: Right femur (control) of rabbit No. 1713.

Fig. 4-B: Left femur of same rabbit, seventy-two hours following operative procedure. The femoral mid-shaft circumference is slightly less than its opposite fellow. The distal epiphysis is widened on its lateral aspect.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Right femur (control) of rabbit No. 1737.

Fig. 5-B: Left femur of same rabbit, twenty-one days following operative procedure. There is still slight retardation of circumferential growth of the mid-shaft. No alteration is present in the distal epiphysis.

sectioned, and stained with hematoxylin and eosin. Some sections were stained with Mallory's analine blue, and others with Weigert's elastic tissue stain.

A second group of twenty mature rabbits were subjected to an identical operative procedure. In these rabbits skeletal growth seemed to have ceased. Despite their apparent maturity, however, some degree of enchondral-bone growth was found in seven of the twenty. Each of the seven animals was killed before the fourth postoperative week; Figure 9 shows the appearance of the most immature epiphyseal cartilage found. The thirteen remaining animals were killed at intervals varying from twenty-four hours to nine months after operation. Serial roentgenograms were not made for any one rabbit in this group.

Alterations Following Stripping of Major Vascular Supply to Rapidly Growing Bone

Thickening of cortical bone was the most noticeable of the gross changes in the animals which showed extensive infarction of bone and marrow. The cortex of the pathological bone was paler in some instances than that of the normal control; its surface was usually roughened in the earlier stages, whereas later it was quite smooth. The marrow in the region of the infarct was soft and pale, occupying the greater portion of the middle half of the shaft. Occasionally a pink rim surrounded the central soft area.

Extensive infarction was seen throughout the middle third of the bone and marrow of the femoral shaft in all animals killed less than two months after operation. This finding was corroborated by an invariable change in this segment, visible in the roentgenogram. After two months, regeneration of marrow and reorganization of bone made histological

FIG. 6

FIG. 7

Fig. 6: Photomicrograph (× 10) of distal femoral epiphysis of rapidly growing rabbit, five days following procedure. A wedge-shaped, subchondral infarct delineated by hemorrhagic border is present (left upper region). Proliferation of cartilage has continued above the area of infarction. Hematoxylin and eosin stain.

Fig. 7: Photomicrograph (× 10) of distal femoral epiphysis of rapidly growing rabbit, ten days after procedure. The cartilage persists, but is being invaded by new vessels in an irregular manner, breaking it up into wafer-like fragments. Hematoxylin and eosin stain.

recognition of the degree of initial injury difficult, but again the roentgenogram confirmed the presence of the lesion by showing changes in the contour as long as four months after the complete or almost complete replacement of infarcted bone with viable tissue. The presence of a yellow lipid-like substance in the marrow cavity permitted a fairly accurate histological delineation of the degree of change that had been present. The distribution of this lipoid substance seemed to establish the fact that widespread injury had been produced in all but one of the rabbits in this series.

The variety of changes produced by these experimental procedures was so great that they must be described separately for each tissue within the bone.

Following surgical division of the vascular supply, the majority of sinusoids in the devascularized tissue collapsed. A few persisted, becoming greatly engorged. Larger arterioles and veins contained blood, but occasionally were filled by fibrin networks, running through an acellular granular material. As early as the fifth postoperative day, proliferating fibroblasts were seen occluding the lumen of some smaller vessels. Later, organization of such arteriolar lumina occurred, and was frequently associated with extensive marrow necrosis which resisted the ingrowth of new myeloid tissue. A partial blood supply through a few sinusoids and arterioles could be recognized in all animals within two months following the operative procedure. Thereafter, no abnormalities in their blood circulatory systems could be seen.

One day after the operation the infarcts were delimited by a hemorrhagic border of extravasated blood and dilated sinusoids. In infarcted marrow tissue, myeloid elements ceased to mature, stained less intensely, and two days later had begun to fragment. By this time, coagulation necrosis of endosteal osteoblasts and osteoclasts was well advanced. The chromatin material from the degenerating hematopoietic substance persisted, either

FIG. 8

FIG. 9

Fig. 8: Photomicrograph (× 10) of distal femoral epiphysis of rapidly growing rabbit, twenty-one days after procedure. The cartilage salient has been erased. Under higher magnification, persisting fragments of cartilage can be seen enclosed in recently formed enchondral bone. Hematoxylin and eosin stain.

Fig. 9: Photomicrograph (× 10) of distal femoral epiphysis of large rabbit. The specimen represents the most immature epiphysis seen in the adult or nearly adult animal. Enchondral-bone formation has nearly ceased, being considerably less in amount than in the rapidly growing animal. Hematoxylin and eosin stain.

engulfed in macrophages or lying free in tissue, and gradually disappeared during the course of a month. Megakaryocytes were the most resistant of all cells to this process of decomposition. As late as two weeks they were still recognizable either as shrunken masses of chromatin, enclosed in an eosinophilic envelope, or engulfed in the cytoplasm of multinucleated giant cells. Erythrocytes rapidly became swollen and lost their usual brilliant eosinophilic character. Hemosiderin could only occasionally be identified in the preparations. The reason for this remained obscure, although failure of erythrocytes to degenerate quickly in bone transplants has been described by Leriche and Policard.

No unusual changes in the marrow lipid were recognized during the first five days after operation, except for a slight variation in the size of the individual fat cells. Anisocytosis became pronounced by the seventh day. At this time refractile, wavy, golden fibrils extended centrally from the cell boundaries into cytoplasmic spaces. Multinucleate, foreign-body type of giant cells formed and presented an abundant cytoplasm which contained as many as seventy-five nuclei. These cells engulfed lipid and cellular debris. The giant cells increased in number until at two weeks, in some instances, they dominated the microscopic field. Their cytoplasm was filled with vacuoles. Some of the vacuoles were almost as large as a fat cell; others were minute globules only a few micra in diameter. After six weeks the vacuoles disappeared and were replaced by a yellow flaky material. Fat cells containing this material maintained their identity for as long as four months, but were not seen in any of the animals of this series after that time. In a previous study, attempts at identifying this substance were not successful. The material was not acid-fast or doubly refractile, but stained blue with Nile-blue sulphate. Although not characterized precisely, it was probably a lipid.[2]

FIG. 10

Photomicrograph (× 10) of cortical bone of nearly adult rabbit, six months following procedure. A shell of viable, new cortical bone encloses the old infarcted tissue, which is poorly reorganized. This arrangement persisted at nine months.

FIG. 11

FIG. 12

Fig. 11: Photomicrograph (× 110) of focus of necrotic lipid enclosed in bone and fibrous tissue of nearly adult rabbit, six months following operative procedure. Hematoxylin and eosin stain.

Fig. 12: Photomicrograph (× 300) of ischaemic necrosis of branches of nutrient artery in marrow infarct. The elastic tissue has collapsed and fallen into the lumina of the arterioles. The surrounding fat cells contain a refractile material that is not removed by the usual fat solvents. Wiegert's method for elastic tissue was used.

A striking alteration in the normal pattern of the enchondral-bone formation followed the experimental procedure. Within twenty-four hours a well defined infarct could be recognized. It appeared as a wedge, the base of which was formed by the epiphyseal cartilage. The borders of the wedge were demarcated by heavy lines of hemorrhagic extravasation. The area of the infarct varied in size, although frequently more than one-half of the enchondral surface of the epiphyseal cartilage was involved. In the central portion of the wedge, vessels became filled with neutrophils as blood flow ceased and newly formed enchondral bone underwent coagulation necrosis. In the necrotic tissue the usual intense eosinophilia of linear streams of provisional bone was replaced in twenty-four hours by a faint basophilia. At the same time osteoblasts and osteoclasts underwent coagulation necrosis. These cells persisted, and were recognized in the ten-day animal by their outline and relationships to bone, although remnants of their nuclear structure were almost gone and their basophilia was lost. Proliferation of cartilage progressed without interruption as occluded vessels failed to resorb the growing columns of cells.

While production of new cartilage cells continued at an approximately normal rate, destruction of cartilage and its replacement by enchondral bone ceased. Thus, the cartilage plate grew within two days to twice its normal thickness, and within five days to almost four times its normal thickness (Fig. 6). These growths were identified in the roentgenograms as widened epiphyses (Fig. 4-B). By the tenth day, new vessels from the periphery had invaded the cartilage mass, forming roughly parallel planes separating irregular, wafer-like segments of cartilage (Fig. 7). Many foci of hemorrhagic extravasation were seen in the cartilage mass. Within twenty-one days the cartilage salient was almost completely erased (Fig. 8). The majority of the affected enchondral bone was removed by osteoclastic activity and rapidly reorganized into cancellous bone. At three weeks, the only remnant of the previous disturbance was a small island of unreorganized infarcted enchondral bone, distinguished by the slender contour of enchondral-bone trabeculae contrasting to the surrounding thicker bars of cancellous bone. Within the healing infarct, irregular clusters of cartilage cells remained.

The operation caused infarction of cortical bone, for, within the first twenty-four hours, the nuclei of the osteocytes had faded and the Haversian vessels were plugged with neutrophils (Fig. 1). Within three days the nuclei of the osteocytes had disappeared, except for occasional groups or clusters. The preservation of the nuclei within all cells located in the outermost cortex was an invariable finding throughout this series. Seventy-two hours after operation circumferential bone growth was demonstrated microscopically, although a slight delay in this process could already be recognized by roentgenogram (Fig. 4-B). New-bone formation was irregular and often massive, occurring in various sized mounds at poorly spaced intervals (Fig. 2). Bone was deposited in part by the osteoblasts of old periosteum as it fell back to cover denuded tissue. In other instances it seemed to be developed from the fascial envelopes of the femur.

Attempted reorganization of the underlying dead cortex was noted within five days, and was characterized by the appearance of small, irregular spaces containing blood vessels, osteoclasts, and osteoblasts. As osteoblasts deposited new bone, the spaces shrank, becoming enclosed by concentric lamellae of deeply eosinophilic bone matrix, in which viable osteocytes were embedded. These tubular deposits of new bone were surrounded by an acellular matrix.

In some instances spaces appeared between the lamellae of dead interstitial bone and widened appreciably. The process of reorganization slowed the rate of circumferential bone growth so that, within three weeks, variations in the diameters of the shaft of the control specimen and the operative side could be differentiated by roentgenographic examination (Fig. 5-B). By this time much of the infarcted cortex had been reorganized (Fig. 3). The lag in growth was compensated for by an irregular mass of new bone which extended toward the abductor group of muscles and developed sufficiently within two months

to form almost normal external contours. Osteoclasts slowly eroded the underlying dead cortex and eventually removed it. After three months, repair of the cortex could be considered complete except for occasional minute foci of dead bone and for the lack of restoration of the pattern of the normal femur.

Alterations Following Stripping of the Major Vascular Supply to Bone Approaching Maturity

Extensive infarction of cortical bone and marrow was found in twelve of the twenty animals of the group approaching maturity. In five, minor degrees of injury to marrow and bone were demonstrated; whereas in the remaining three, no infarcts were found. The presence or absence of an epiphyseal plate was not related to these results. The extensive infarcts were distributed in a manner similar to that which occurred in the younger rabbits. The infarcts were observed from seventy-two hours to nine months after the operation.

The earlier sequences in the formation of infarcts resembled those previously described. However, the slower regenerative processes of the older animals enabled the investigators to study the later stages of infarction of bone and bone marrow. Such a study was impossible in the rapidly growing animals of Group I.

Slowing of reorganization occurred in nearly all of the bones of the animals in this group. Large areas of necrotic cortex were observed among the cylinders of recently formed bone, even nine months after operation. Heavy depositions of appositional bone, in which Haversian systems failed to appear, enclosed the infarcted bone segments in a discrete shell. A similar inner shell was often seen in the repair of endosteal bone. This inner shell of endosteal bone, together with the thick rim of appositional bone, increased the density of the cortex (Fig. 10).

Similarly, the injury to the marrow failed to repair quickly. The peculiar golden lipoid substance seen in fat cells following infarction became pooled as the cell boundaries of the fat cells were fragmented and disappeared. Large lipoid aggregates were rarely associated with the formation of cysts, the cyst appearing as a small unstained clear area in the central part of the lesion. Fibrous-tissue septa often grew in and about the clusters of yellow lipid-like material. Bone formation was seen in the marrow of two of the bones of the rabbits studied six months after operation. The new-bone formation was found in the neighborhood of these fibrous-tissue accumulations (Fig. 11). Myeloid elements regenerated very slowly in the areas of infarction within the marrow. In one compartment of infarcted marrow, a small arteriole was found, which had undergone coagulation necrosis with subsequent collapse of its elastic tissue. The intimal fibroblasts had not multiplied in this destroyed vessel (Fig. 12).

DISCUSSION

Following interruption of the nutrient vessels and stripping of the periosteum, infarction of bone and bone marrow occurred in thirty-three of the thirty-six animals used in this study. The occasional failure of infarction to occur in the bones of the older animals, in spite of a major insult to the blood supply, could be explained by an adequate collateral blood supply reaching the interior of the bone by way of the large perforating vessels. This is in accordance with Langer's description, quoted by Drinker and his associates. The pattern of infarction involved the entire bone cortex in the middle third of the femur. This finding was more constant in rapidly growing animals than in those which were more mature. Infarction of marrow occurred in sites in which larger vessels had been occluded. Such sites were recognized first by an abnormal accumulation of neutrophils and of wisps of fibrin. In some instances the obliteration of blood flow was recognized by the presence of a proliferative endarteritis. However, a precise description of the changes in blood flow which resulted from this surgical procedure could not be made by a study of this material. Consequently, the clarification of this aspect of the experiment must be left for another investigation. Occasionally cortical necrosis occurred over uninfarcted myeloid

tissue (Fig. 3), but in most instances was associated with an injured marrow. In very young animals, the combined operation was always followed by infarction of enchondral bone.

Earliest reparative response to the presence of an infarct in the marrow space was made by the macrophages which engulfed lipid and cellular debris. Later, the macrophages were replaced by irregularly shaped cells containing a golden-brown lipid-like substance, resembling that described by Bragdon, Foster, and Sosman. The presence of this fatty-like material for months was associated with the development of capsules of fibrous tissue and, in some instances, of bone. When only the nutrient vessels were severed,[2] no fibrosis was observed; the lipoid substance, present in smaller quantity, was scattered more diffusely. In the present series of rabbits, the frequent appearance of fibrous tissue and bone production with necrosis of lipid suggested that the fat substance in all probability stimulated the activity of fibroblasts and osteoblasts. In the photomicrographs illustrating Kistler's study, a similar relationship of myelofibrosis to fat necrosis was shown. In Kistler's experiments, deposition of bone and fibrous tissue in the marrow space reached its peak two months after injection of particulate matter into the femoral artery. In our series of animals, the deposition of bone and fibrous tissue did not occur in the younger rabbits, although it did occur in the older animals and became maximum six months after the operation. No particular infarct in any rabbit of this series duplicated the lesions attributed to infarction in necropsy specimens of adult human long bones. Cyst formation was rare, although fat necrosis, myelofibrosis, and bone formation were changes common to our animals and to the lesions described in humans. Neither necrotic bone persisting in the marrow space nor calcified lipid, so characteristic of the human infarct of long bones, was found in this series of rabbits.

The wedge-shaped infarcts of uniform size in enchondral bone were best studied in the younger group of animals, because they invariably followed the experimental procedure. The continued proliferation of cartilage cells in the bones of these animals indicated that the nutritional requirement of this substance not only was low, but also could be supplied solely from the blood vessels from the epiphysis. In one of Kistler's experimental animals (nine days after carbon injection), cartilage necrosis followed infarction of the epiphysis, thus emphasizing the necessity of an intact epiphyseal blood supply. Whereas Kistler reported frequent shortening of bone following his method of producing infarcts, no apparent interference with longitudinal bone growth resulted from the infarction of epiphyseal cartilage plate and of newly formed enchondral bone in our animals. In most instances the lengths of the bone operated upon were equal to those of the normal bone, although minor differences were occasionally found. Lengthening resulted as often as shortening. This discrepancy between the results of Kistler and those of the writers might be explained by the finding of Lacroix that stimulation of longitudinal bone growth followed stripping of diaphyseal periosteum. Although Kistler took great pains to avoid injuring the periosteum, nonetheless the metaphysis of bone was frequently injured by carbon emboli. In our series, although metaphyseal injury invariably occurred, it followed extreme insult to the periosteum. The rapidity of removal of the cartilage salient indicated that this tissue had been uninjured by the experimental procedure. The slower removal of recently formed infarcted enchondral bone was probably the result of imperfect revascularization, since osteoclasts and osteoblasts were active about the periphery of the lesion. No deformities appeared following infarction abutting the epiphyseal cartilage plate.

Our results emphasize that loss not only of endosteal but also of periosteal blood supply is a determinant factor in the production of complete infarction of cortical bone. If the source of either one of these blood supplies remained, foci of viable cortex persisted. Occasional exceptions to this pattern of infarction were noted where the nutrient vessels were cut [2] and the periosteum was left intact. The lesions produced by such a procedure were small and were confined to the endosteal portion of the cortex of the bone.

SUMMARY

Cutting the nutrient vessels of the femur, together with stripping of its periosteum, was invariably followed by extensive infarction of bone and of bone marrow in young, rapidly growing rabbits. Impairment in the rate of circumferential growth accompanied cortical infarction, but no delay in longitudinal growth was found after infarction of enchondral bone. The cortical infarcts in the bones of the animals of this series were almost completely repaired within two months except for changes in contour, whereas the sequences of enchondral-bone formation became normal three weeks after the operation.

In animals approaching maturity, the operation produced varied results. Persistence of marrow infarcts for periods of five months or more accompanied ingrowths of fibrous tissue, and occasionally stimulated the production of bone within the marrow compartment. Cortical infarcts in the bones of these animals were repaired so slowly that large amounts of dead bone were present for as long as nine months after the initial injury.

REFERENCES

1. Axhausen, G.: Die aseptische Knochennekrose und ihre Bedeutung für die Knochen- und Gelenkchirurgie. Acta Chir. Scandinavica, **60:** 369–396, 1926.
2. Bergmann, Ernst: Theoretisches, klinisches und experimentelles zur Frage der aseptischen Knochennekrosen. Deutsche Ztschr. f. Chir., **206:** 12–87, 1927.
3. Bragdon, J. H.; Foster, Lee; and Sosman, M. C.: Experimental Infarction of Bone and Marrow. Am. J. Pathol., **25:** 709–723, 1949.
4. Brunschwig, Alexander: Experimental Infarction of Bone Marrow. Proc. Soc. Exper. Biol. and Med., **27:** 1049–1051, 1930.
5. Drinker, C. K.; Drinker, K. R.; and Lund, C. C.: The Circulation in the Mammalian Bone-Marrow. Am. J. Physiol., **62:** 1–92, 1922.
6. Haldeman, K. O.: The Rôle of Periosteum in the Healing of Fractures. An Experimental Study. Arch. Surg., **24:** 440–450, 1932.
7. Huggins, Charles, and Wiege, Eugene: The Effect on the Bone Marrow of Disruption of the Nutrient Artery and Vein. Ann. Surg., **110:** 940–947, 1939.
8. Johnson, R. W.: A Physiological Study of the Blood Supply of the Diaphysis. J. Bone and Joint Surg., **9:** 153–184, Jan. 1927.
9. Kahlstrom, S. C.; Burton, C. C.; and Phemister, D. B.: Aseptic Necrosis of Bone. I. Infarction of Bones in Caisson Disease Resulting in Encapsulated and Calcified Areas in Diaphyses and in Arthritis Deformans. Surg., Gynec., and Obstet., **68:** 129–146, 1939.
10. Kahlstrom, S. C.; Burton, C. C., and Phemister, D. B.: Aseptic Necrosis of Bone. II. Infarction of Bones of Undetermined Etiology Resulting in Encapsulated and Calcified Areas in Diaphyses and in Arthritis Deformans. Surg., Gynec., and Obstet., **68:** 631–641, 1939.
11. Kistler, G. H.: Sequences of Experimental Infarction of the Femur in Rabbits. Arch. Surg., **29:** 589–611, 1934.
12. Kistler, G. H.: Sequences of Experimental Bacterial Infarction of the Femur in Rabbits. Surg., Gynec., and Obstet., **60:** 913–925, 1935.
13. Kistler, G. H.: Effects of Circulatory Disturbances on the Structure and Healing of Bone. Injuries of the Head of the Femur in Young Rabbits. Arch. Surg., **33:** 225–247, 1936.
14. Kolodny, Anatole: The Periosteal Blood Supply and Healing of Fractures. Experimental Study. J. Bone and Joint Surg., **5:** 698–711, Oct. 1923.
15. Lacroix, Pierre: Excitation de la croissance en longueur du tibia par décollement de son périoste diaphysaire. Rev. d'Orthop., **33:** 3–6, 1947.
16. Langer: Cited by Drinker et al.
17. Leriche, R., and Policard, A.: The Normal and Pathological Physiology of Bone. Its Problems. (English translation by S. Moore and J. A. Key.) St. Louis, C. V. Mosby Co., 1928.
18. Phemister, D. B.: Changes in Bones and Joints Resulting from Interruption of Circulation. I. General Considerations and Changes Resulting from Injuries. Arch. Surg., **41:** 436–472, 1940.
19. Phemister, D. B.: Changes in Bones and Joints Resulting from Interruption of Circulation. II. Nontraumatic Lesions in Adults with Bone Infarction; Arthritis Deformans. Arch. Surg., **41:** 1455–1482, 1940.
20. Wollenberg: Cited by Axhausen.

FIBROUS DYSPLASIA OF BONE *

BY PAUL STRASSBURGER, M.D., C. ZENT GARBER, M.D., AND HALFORD HALLOCK, M.D., NEW YORK, N. Y.

From the New York Orthopaedic Hospital, New York City

To the orthopaedic surgeon, fibrous dysplasia of bone as a disease entity is a relatively new condition. It is a clinical syndrome that may present itself in various ways. Patients with fibrous dysplasia of bone may be divided into three groups: first, those with single or multiple lesions in one bone; second, those with lesions in several bones, with or without skin pigmentation; third, those with multiple bone lesions, dermal pigmentation (of the *café au lait* type), and precocious puberty, either alone or in association with early skeletal maturation. The lesions of the skin, bones, and endocrine system in the third group were considered by McCune in 1936 [17,18] as a clinical syndrome; it is this group which sets the disease apart from osteitis fibrosa cystica.

Lichtenstein and Jaffe, in 1942, used the term fibrous dysplasia of bone and separated the disease into the three clinical types listed in the preceding paragraph. The disease has been designated by a number of different terms, including osteodystrophia fibrosa [18], osteitis fibrosa disseminata [1,3], and polyostotic fibrous dysplasia [15]. Weil, in 1922, recorded the first case to be found in the literature. Notable are two complete autopsy reports by Uehlinger and by Sternberg and Joseph. By a rough estimate, about two hundred cases have now been reported and there have been a number of recent reviews and illuminating case reports [2,4,8–12,14,21,23].

FIG. 1

Case 2. Diffuse bone lesions with areas of decreased density and ground-glass appearance in a girl, aged twelve years.

The etiology of fibrous dysplasia is unknown. It is most probably a developmental defect [16]. However, the fact that the three different systems involved in the complete syndrome arise from different embryological tissues gives some countenance to the theory of a central or nervous-system lesion [3,11].

The clinical manifestations

* Presented before the Section on Orthopaedic Surgery at the Ninety-eighth Annual Session of the American Medical Association, Atlantic City, New Jersey, June 8, 1949.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 1. Cystlike area of decreased density at proximal portion of femoral shaft in a girl, aged six years.

Fig. 2-B: Expansion and thinning of the cortex with osteoporosis and bowing when child was ten years of age.

Fig. 2-C: Sclerosis of base of skull when child was twelve. Clinically there was proptosis and early leontiasis ossea, asymmetrically.

Fig. 2-D: Femur with thin cortex. Medulla is firm to soft cancellous bone, containing large islands of cartilage.

of the disease are variable and depend upon which factor is dominant. The bone lesions usually are insidious in onset. The first knowledge of any trouble may follow a fracture through a diseased area of bone. However, in most instances of involvement of the lower extremities there is pain, limp, and limitation of motion with gradual progression of symptoms.

The roentgenographic findings also are variable and are dependent upon the stage of the disease. The earliest manifestations are areas of decreased density within the cortical structure with a rather diffuse ground-glass appearance (Fig. 1). These are *not* cysts, but areas in which the normal bony trabeculae (Fig. 2-A) have been replaced with fibrous and osteoid tissue, the density of which is less than that of normal bone. At times the lesions show a more diffuse appearance with areas of both decreased and increased density (Fig. 3-A).

As the lesions progress, the involved areas increase in size and in many instances expansion and thinning of the cortex occur (Fig. 2-B), accompanied by local osteoporosis and bowing of the bones. A great deal of variability exists in these lesions and they do not all progress; many remain static for years (Fig. 4).

FIG. 2-C

FIG. 2-D

The laboratory findings in these patients practically always are within normal limits except that the alkaline phosphatase frequently is elevated [8,9]. The basal metabolic rate may be elevated if there is concomitant hyperthyroidism [3,18,24].

The differential diagnosis from hyperparathyroidism is made on the basis of age incidence (usually adults), generalized bone decalcification, and the high blood calcium and low blood phosphorus levels found in hyperparathyroidism. In spite of this, in about 30 per cent. of the cases reported in the literature, exploration was made for parathyroid tumor; in no recorded instance was any found.

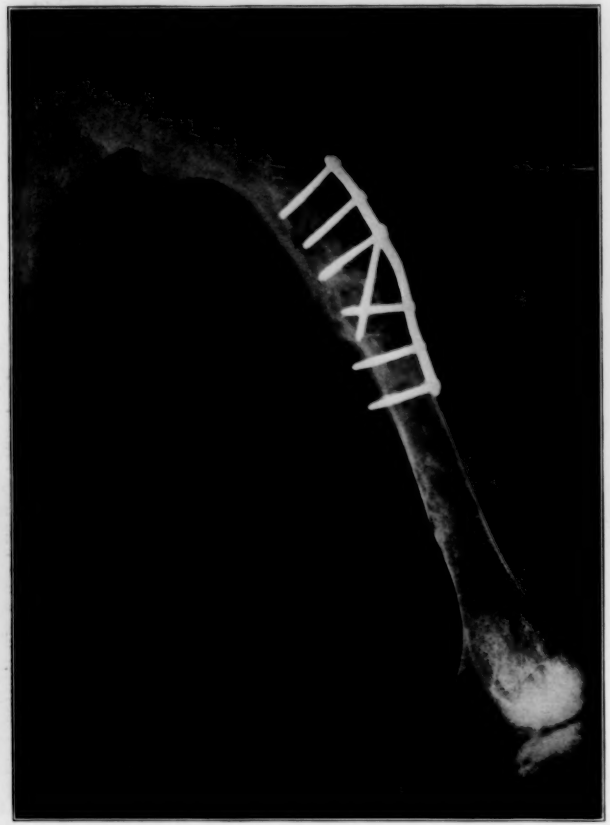


FIG. 2-E

FIG. 2-F

Fig. 2-E: After correction of bowing of femur.

Fig. 2-F: After correction and recurrence of deformity above site of osteotomies.

Fig. 2-G: Cartilaginous and fibrous dysplasia of femur.

Fig. 2-H: Skin pigmentation, sexual precocity, and bony deformities of femora seen when child was twelve years of age.

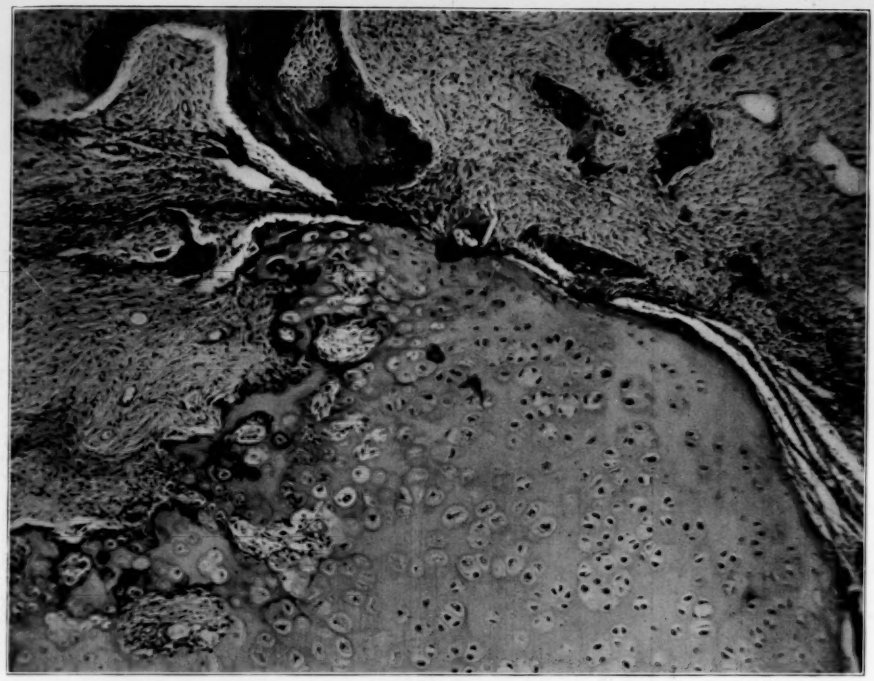


FIG. 2-G

In sarcoid, the bone lesions generally are limited to or are most marked in the hands. The elevation of total plasma proteins, frequent reversal of the albumin-globulin ratio, and the characteristic skin, lung, and eye lesions differentiate this condition.

Paget's disease of bone (osteitis deformans) occurs mostly in the fourth, fifth, and sixth decades of life. The roentgenographic appearance of thickening of the cortex with narrowing of the medullary cavity and the histological appearance of biopsy specimens are diagnostic.

Multiple myeloma is seen practically always after the age of forty. It is usually characterized by elevated protein and high calcium levels; in about one-half of the patients, Bence-Jones protein is present in the urine. Histologically, the bone marrow shows the typical myeloma cells.

Malignant osteolytic medullary neoplasms, primary and secondary, are mentioned only to complete the list.

While skeletal enchondromatosis (dyschondroplasia, Ollier's disease) may have unilateral tendencies, the absence of microscopic enchondromata in the metacarpal, metatarsal, and phalangeal bones and the absence of associated lesions, including greatly shortened extremities and cartilaginous exostoses, rule out this condition. The membranous bones of the skull and the diaphyseal portions of long bones escape in dyschondroplasia. Microscopically, the appearances are different [16,21].

Hand-Schüller-Christian disease (lipoid granulomatosis) may be confused with fibrous dysplasia when roentgenograms reveal large radiolucent areas in the skull, as these may be found in both conditions. Histological examination of the tissue, however, differentiates the conditions.

Bone cyst, giant-cell tumor, and osteitis fibrosa localisata are all single lesions, and the roentgenographic and histological appearances of the first two at least are characteristic. We conceive osteitis fibrosa as representing a healed or healing stage of some

TABLE I

CLINICAL FINDINGS IN NINE CASES

Case and Sex	Initial Complaint	Age at Onset (*Years*)	Skin Pigmentation	Sexual Precocity	No. of Bones Involved	Phosphatase*	Fractures	Deformity	Surgery	Cartilage Nodules	Present Age (*Years*)	Condition
1, F. E. L.	Fracture left femur	5	Yes	Yes	15	16.7 14.2 13.6	Multiple pathological	Severe bowing, bilateral	Curettage and bone chips (2); osteotomy (3)	Large and small	12	Uses braces
2, F. Z. K.	Early menstruation	1½	Yes	Yes	12	12.4	Stress fracture, femur	Coxa vara and bowing	No		21	Asymptomatic
3, M. J. E.	Pain, right hip and knee	10	No	No	5		No	Coxa vara	Curettage and bone chips	Microscopic	14	No pain, short leg
4, M. P. R.	Pain, right hip	33	No	No	3	2.7	Stress fracture, femur	No	Biopsy	Very large	40	Asymptomatic
5, F. O. M.	Pain, left leg	9	No	No	4	2.5	Stress fracture, femur	No	No		48	Asymptomatic
6, M. S. G.	Pain and limp, right hip	11	Yes	No	1	8.6	Femur	No	Curettage and bone chips	No	16	Full activity
7, F. R. P.	Deformity, left tibia	1¼	Yes	No	2		Left tibia	Bowing of tibia	Two bone grafts (previously)	No	8	Non-union, left tibia
8, F. J. M.	Pain, left leg	6	No	No	1	3.0	Left femur	Bowing of femur	Curettage and bone chips	Large	21	Uses a long brace
9, M. L. M.	Fracture, right ulna	4	Yes	No	1		Right ulna	No	Curettage and bone chips	No	5	Recovering

* Bodansky units.

FIG. 3-A

FIG. 2-H

FIG. 3-C

FIG. 3-B

Fig. 3-A: Case 3. Areas of apparent increased density at proximal portions of ulnae with other areas of decreased density in shaft of a boy, aged twelve years.

Fig. 3-B: Biopsy specimen of sclerotic proximal portion of ulna. Cortex and medulla formed of thick immature bone trabeculae. Marrow replaced by fine-fibered connective tissue.

Fig. 3-C: Cartilaginous and fibrous dysplasia of femur.

Fig. 4: Case 4. Ilium and femur of a man, aged thirty-nine years. No change during a six-year period of observation.

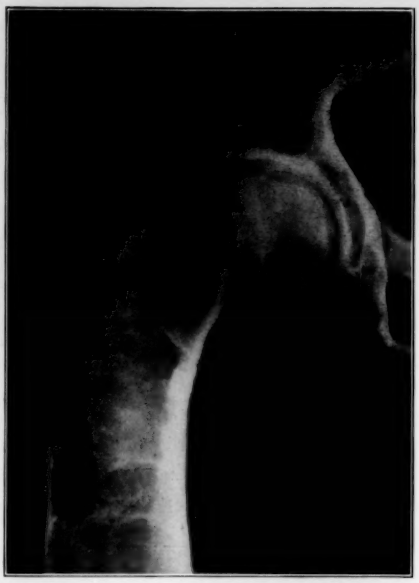


FIG. 4

preceding injury, and so look particularly for evidence of old hemorrhage, old fracture, a disturbance of blood supply, or infection. When osteoid tissue is also present as part of the reparative process, small areas may histologically resemble the picture of fibrous dysplasia. Such areas can often be found in the walls of bone cysts or in parts of giant-cell tumors, but they are small in volume. Osteitis fibrosa is a wastebasket for fibrous scars, usually of unknown origin. We should not use the term fibrous dysplasia in the same way. Schlumberger, in a report of sixty-seven cases of monostotic fibrous dysplasia among army personnel without other stigmata of the syndrome, concluded that this monostotic form is not a congenital anomaly, and etiologically probably has nothing in common with the polyostotic dysplasia found in the complete syndrome. He thought it might represent a disturbance of the normal reparative processes following any of a variety of bone injuries. If this is somewhat confusing, it is because our picture of the disease is incomplete.

In neurofibromatosis (von Recklinghausen's disease), the distribution of the pigmentation [2], the presence of cartilaginous exostoses and other deforming malformations, and the histological appearance separate this condition [13].

The picture of leontiasis ossea may be produced by fibrous dysplasia as well as by ossifying fibroma, acromegaly, and Paget's disease. Sclerotic changes at the base of the skull are common in fibrous dysplasia [9,11,20] (Fig. 2-C). Proptosis, narrowing of the visual fields, and deafness may follow secondarily.

TABLE II

DISTRIBUTION OF LESIONS

	Number of Cases		
	Right	Left	
Femur	5	4	
Tibia	2	4	
Fibula	2	2	
Talus		1	
Metatarsals and phalanges			2
Skull			3
Spine			2
Pelvis	3	3	
Humerus	1	1	
Radius	1	2	
Ulna	3	2	
Metacarpals and phalanges			1

TABLE III

RESULTS OF CURETTAGE AND USE OF BONE CHIPS

Case No.	Results of Curettage	Type of Bone Chips Used
1	Chips absorbed on two occasions	Syngenesious
3	Lesion healed	Autogenous and homogenous (bone bank)
6	Lesion healed	Autogenous
8	Chips absorbed	Autogenous
9	Lesion healed	Homogenous (bone bank)

The authors' clinical experience with this disease is based on nine cases, — four males and five females (Table I). Three patients had monostotic lesions, four had polyostotic lesions, and two had the full symptom complex of polyostotic lesions, skin pigmentation, and sexual precocity, with or without early skeletal maturation.

Eight of these patients had initial complaints of an orthopaedic nature, — that is, fracture, pain, or deformity of an extremity. The age at onset ranged from fifteen months to thirty-three years. There was skin pigmentation of the *café au lait* type in five of the patients. Sexual precocity was seen only in the two patients with the full syndrome com-

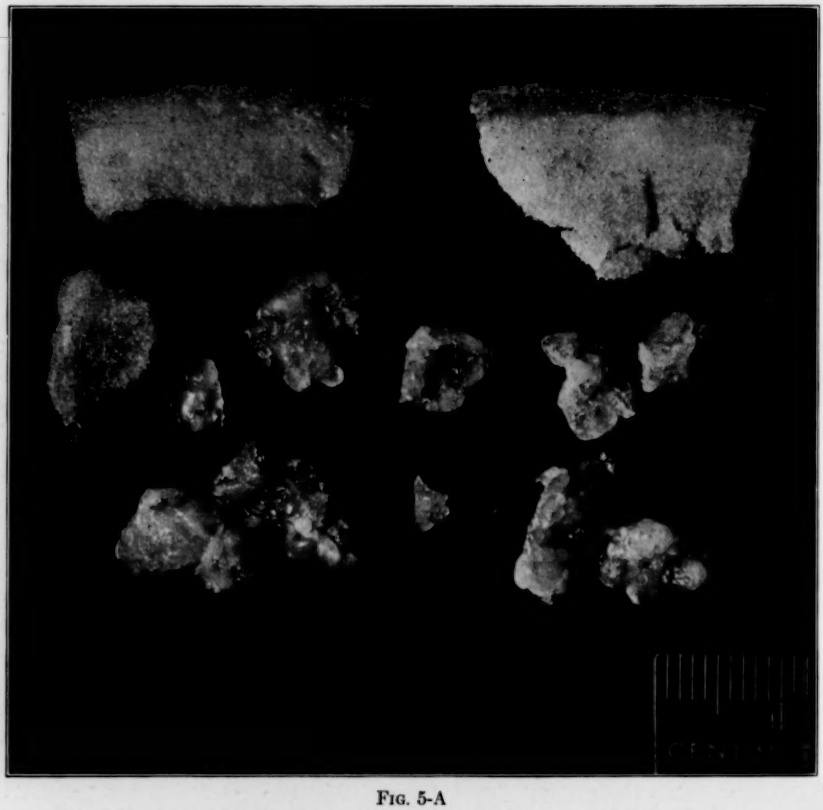


FIG. 5-A

Case 8. Cartilaginous and fibrous dysplasia of femur, with thin cortex. The rounded glistening fragments are nodules of cartilage.

Fig. 5-B: Connective tissue of femur with "curly" pattern in metaplasia to osteoid tissue.

Fig. 6: Case 6. Metaplasia of connective tissue of femur to osteoid tissue.

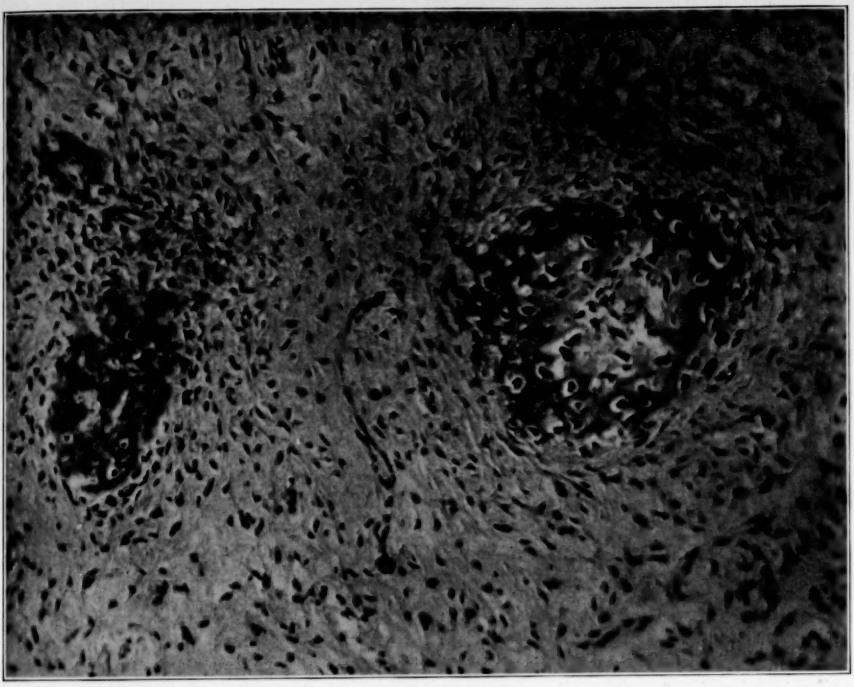


FIG. 6

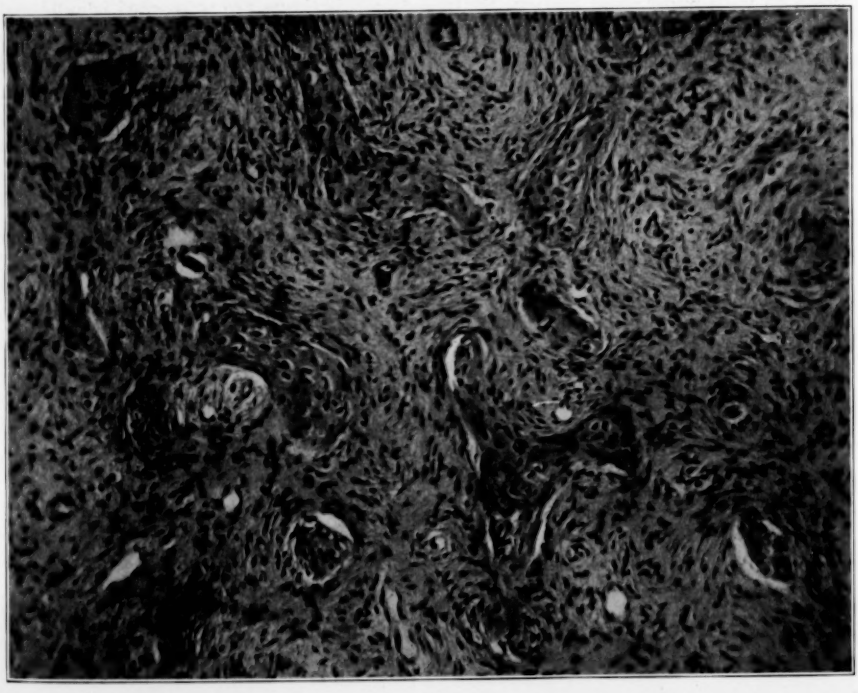


FIG. 5-B

plex. The number of bones involved ranged from one to fifteen with distribution as noted in Table II. The alkaline phosphatase was elevated in two cases. There was only one patient who did not have a fracture at some time during the period of observation. Five of the patients showed deformities ranging from mild coxa vara to severe genu varum. Their present ages range from five to forty-eight years.

Our pathological findings are based on examination of thirteen surgical specimens from nine bones of seven patients. Grossly, there was replacement of medulla and partial replacement of an expanded, thinned cortex by grayish-white, reddish, or grayish-yellow, firm, somewhat elastic, granular, gritty tissue; this could usually be cut with a knife and had a palpable texture and a resistance to incision simulating that of unripened melon or firm sponge rubber (Fig. 5-A). The cortex varied in thickness from 0.3 to 2 millimeters in most instances. In the biopsy specimen from the ulna of Case 3, however, the medulla (proximal end, right) was filled with moderately compact bone, indistinguishable from that occupying the cortical zone. Rounded nodules of bluish-white, semitranslucent, resilient hyaline cartilage were present in the abnormal tissue of five bones from four patients, varying in diameter from several centimeters in Case 4 to a small size requiring microscopic verification in Case 3. In Case 1, half of the cross section of the femur was made up of cartilage (Fig. 2-D). Cartilage was not found in specimens from four bones of three patients. In the literature, eight cases have been noted in which cartilage was reported [1,5,8,15,16,19,24,25].

Microscopic examination showed the abnormal tissue to be composed of spindle or somewhat stellate cells with long, projecting, interwoven, fine fibers which stain like reticulin. A tendency for these delicate fibers to be arranged parallelly and in whorls gives a characteristic "curly" appearance (Fig. 5-B). In some areas these cells exhibit coarser fibers of collagen and are identified as connective-tissue cells. Such tissue is often found in Haversian canals of compact bone in the early stage of atrophy. Osteoclastic activity is associated with more rapid erosion. Scattered in this tissue are numerous islands and narrow irregular trabeculae of osteoid tissue formed by metaplasia of the connective-tissue cells (Fig. 6). Much of this osteoid tissue is partly calcified and some has developed to long, narrow, curved trabeculae of immature bone. Less frequently, the formation of wider and more numerous trabeculae results in sclerosis, as seen in the biopsy specimen from the ulna of Case 3 (Fig. 3-B) and in the roentgenogram of the base of the skull of Case 1 (Fig. 2-C).

Islands of hyaline cartilage, when present, usually show a rounded, sharply defined edge somewhere at the periphery. Elsewhere at the periphery they exhibit transition to bone, simulating that at the margin of an epiphyseal plate, with growth sometimes active and sometimes quiescent (Figs. 2-G and 3-C). The cartilage is adult in type. Just beyond the large nodules at times there may be seen some metaplasia of connective tissue to cartilage. The cartilage nodules, when large, tend to degenerate centrally. The peripheral zones of growth exhibit calcification of matrix.

Areas of oedema are frequent and there may be associated degeneration. Small hemorrhages are often seen at the margins of the trabeculae of osteoid tissue. Some hemosiderin can be found in phagocytes. Blood capillaries in general are only moderately numerous, but their walls are often dilated and quite thin. Perivascular oedema may be extreme.

Massive hemorrhage with cystic degeneration has explained two cases with apparent rapid clinical growth of lesions of fibrous dysplasia, reported in the literature [14,22]. Since there are now four recorded cases of sarcoma developing in association with fibrous dysplasia, it is indicated that patients with this disease be kept under medical supervision [6,7,14].

Because fibrous tissue and osteoid tissue are manifestations of repair in a number of bone conditions, the pathologist chooses to be conservative in making an independent diagnosis of fibrous dysplasia from a small biopsy specimen and does not hesitate to qualify his diagnosis with such terms as "probable" or "consistent with". When cartilage

is present, the diagnosis becomes certain. Qualifying terms can be omitted when histological findings are added to pigmentation of the skin or to other sufficiently suggestive clinical and roentgenographic features of this disease.

In five of the nine cases (Table III) curettage of the bone lesions and packing of the areas with bone chips were carried out. In the three cases with relatively small lesions, there were good results. In the two patients with large lesions, the chips were absorbed on three occasions. In one patient osteotomies were performed (Fig. 2-E) to correct the severe bowing. The bone at the site of osteotomy united, but the deformities have begun to recur above the level of the osteotomies (Figs. 2-F and 2-H).

SUMMARY

Experience with nine cases indicates that fibrous dysplasia of bone may present a variable clinical picture. In adults there may be rather extensive lesions in more than one bone without symptoms or serious impairment of function. The solitary lesions respond to curettage and packing with bone chips, but this procedure was not beneficial in treating large lesions, where the abnormal tissue could not be entirely removed. In the usual case a summation of clinical, roentgenographic, and microscopic findings is desirable for diagnosis of this disease. When islands of cartilage are present, the diagnosis can be made on the basis of the gross or microscopic examination alone.

REFERENCES

1. Albright, Fuller; Butler, A. M.; Hampton, A. O.; and Smith, Patricia: Syndrome Characterized by Osteitis Fibrosa Disseminata, Areas of Pigmentation and Endocrine Dysfunction, with Precocious Puberty in Females. Report of Five Cases. New England J. Med., **216:** 727–746, 1937.
2. Albright, Fuller, and Reifenstein, E. C., Jr.: Parathyroid Glands and Metabolic Bone Disease. Selected Studies, p. 263. Baltimore, Williams and Wilkins Co., 1948.
3. Albright, Fuller; Scoville, Beecher; and Sulkowitch, H. W.: Syndrome Characterized by Osteitis Fibrosa Disseminata, Areas of Pigmentation, and a Gonadal Dysfunction. Further Observations Including the Report of Two More Cases. Endocrinology, **22:** 411–421, 1938.
4. Bingold, A. C.: A Case of Polyostotic Fibrous Dysplasia. British J. Surg., **36:** 22–26, 1948.
5. Braid, Frances: Osseous Dystrophy Following Icterus Gravis Neonatorum: Generalized Osteitis Fibrosa with Areas of Pigmentation of the Skin and Precocious Puberty in the Female. Arch. Dis. Childhood, **14:** 181–202, 1939.
6. Coley, B. L.: Neoplasms of Bone and Related Conditions. Their Etiology, Pathogenesis, Diagnosis, and Treatment, p. 148. New York, Paul B. Hoeber, 1949.
7. Coley, B. L., and Stewart, F. W.: Bone Sarcoma in Polyototic Fibrous Dysplasia. Ann. Surg., **121:** 872–881, 1945.
8. Dockerty, M. B.; Ghormley, R. K.; Kennedy, R. L. J.; and Pugh, D. G.: Albright's Syndrome. (Polyostotic Fibrous Dysplasia with Cutaneous Pigmentation in Both Sexes and Gonadal Dysfunction in Females.) Arch. Int. Med., **75:** 357–375, 1945.
9. Falconer, M. A.; Cope, C. L.; and Robb-Smith, A. H. T.: Fibrous Dysplasia of Bone with Endocrine Disorders and Cutaneous Pigmentation (Albright's Disease). Quart. J. Med., **11:** 121–154, 1942.
10. Furst, N. J., and Shapiro, Robert: Polyostotic Fibrous Dysplasia: Review of the Literature with Two Additional Cases. Radiology, **40:** 501–515, 1943.
11. Goldhamer, Karl: Osteodystrophia fibrosa unilateralis (kombiniert mit Pubertas praecox und mit gleichseitigen osteosklerotischen Veränderungen des Schädels). Fortschr. a. d. Geb. d. Röntgenstrahlen, **49:** 456–481, 1934.
12. Gorham, L. W.; Campbell, E. H.; Howard, W. P.; Donhauser, J. L.; and Rust, N. H.: Albright's Syndrome. A Group of Cases Characterized by Osteitis Fibrosa Disseminata, Areas of Pigmentation and a Gonadal Dysfunction. Clinics, **1:** 358–385, 1942.
13. Jaffe, H. L.: Fibrous Dysplasia of Bone. A Disease Entity and Specifically not an Expression of Neurofibromatosis. J. Mount Sinai Hosp., **12:** 364–380, 1945.
14. Jaffe, H. L.: Fibrous Dysplasia of Bone. Bull. New York Acad. Med., **22:** 588–604, 1946.
15. Lichtenstein, Louis: Polyostotic Fibrous Dysplasia. Arch. Surg., **36:** 874–898, 1938.
16. Lichtenstein, Louis, and Jaffe, H. L.: Fibrous Dysplasia of Bone. A Condition Affecting One, Several or Many Bones, the Graver Cases of Which May Present Abnormal Pigmentation of Skin, Premature Sexual Development, Hyperthyroidism or Still Other Extraskeletal Abnormalities. Arch. Pathol., **33:** 777–816, 1942.

17. McCune, D. J.: Osteitis Fibrosa Cystica; the Case of a Nine Year Old Girl who also Exhibits Precocious Puberty, Multiple Pigmentation of the Skin and Hyperthyroidism. Trans. Soc. Pediatric Research, May 5, 1936. *In* Am. J. Dis. Child., **52:** 743–747, 1936.
18. McCune, D. J., and Bruch, Hilde: Osteodystrophia Fibrosa. Report of a Case in Which the Condition Was Combined with Precocious Puberty, Pathologic Pigmentation of the Skin and Hyperthyroidism, With a Review of the Literature. Am. J. Dis. Child., **54:** 806–848, 1937.
19. O'Donovan, D. K.; Duff, F.; O'Farrell, T. D.; and McGrath, J.: Polyostotic Fibrous Dysplasia. Irish J. Med. Science, pp. 498–504, Sept. 1944.
20. Pugh, D. G.: Fibrous Dysplasia of the Skull: A Probable Explanation for Leontiasis Ossea. Radiology, **44:** 548–555, 1945.
21. Sante, L. R.; Bauer, Wm.; and O'Brien, R. M.: Polyostotic Fibrous Dysplasia (Albright's Syndrome) and Its Comparison with Dyschondroplasia (Ollier's Disease). A Correlation of the Radiological and Pathological Findings. Radiology, **51:** 676–690, 1948.
22. Schlesinger, P. T.; Keats, Sidney; and Ruoff, A. C., III: Fibrous Dysplasia. Report of a Case. J. Bone and Joint Surg., **31-A:** 187–191, Jan. 1949.
23. Schlumberger, H. G.: Fibrous Dysplasia of Single Bones (Monostotic Fibrous Dysplasia). Milit. Surgeon, **99:** 504–527, 1946.
24. Sternberg, W. H., and Joseph, Vera: Osteodystrophia Fibrosa Combined with Precocious Puberty and Exophthalmic Goiter. Pathologic Report of a Case. Am. J. Dis. Child., **63:** 748–783, 1942.
25. Telford, E. D.: A Case of Osteitis Fibrosa (with Formation of Hyaline Cartilage). British J. Surg., **18:** 409–414, 1931.
26. Uehlinger, E.: Osteofibrosis deformans juvenilis (Polyostotische fibrose Dysplasie Jaffe-Lichtenstein). Virchow's Arch. f. Path. Anat., **306:** 255–299, 1940.
27. Weil: Pubertas praecox und Knochenbrüchigkeit. *In* Medizinische Sektion der Schlesischen Gesellschaft für vaterländische Kultur zu Breslau. Klin. Wchnschr., **1:** 2114–2115, 1922.

DISCUSSION

Subtrochanteric Osteotomy and Spline Fixation

(*Continued from page 395*)

These are difficult operations, but we are dealing with a most difficult problem, and perhaps we cannot afford to shun radical methods.

I have enjoyed this presentation very much and shall be interested to learn of the later results.

Dr. Mather Cleveland (closing): One of the most important things under discussion is non-union of the fractured neck of the femur. Dr. Cave has stated that inadequate reduction and inadequate nailing are responsible for a persistent residuum of ununited fractures of the neck of the femur. The problem is extraordinarily difficult and perhaps this isn't the answer, but it may be in some instances. Rotational osteotomy in itself is a difficult procedure and is not to be undertaken lightly. With our best efforts to secure adequate reduction and accurate nailing of the intracapsular fracture, we, at St. Luke's Hospital, have been able to secure union in only approximately 80 per cent. of displaced fractures. In cases where we know at the time that we have failed, I wonder if this osteotomy might not be done at the time of the original procedure, if the patient is a reasonable operative risk. Apparently some of you do not agree, but we have had it in mind.

A great deal of this surgery has been necessitated by our own shortcomings,—that is, our inability to reduce and properly fix these fractures of the neck of the femur. We have been particularly pleased with the results in the cases of congenital coxa vara. In spite of what Dr. Colonna says, our children with fractures of the neck of the femur did extremely well. This is a preliminary report and perhaps we may have to revise our opinions some day.

OSTEITIS DEFORMANS

A Theory of Its Etiology

BY SHERWOOD MOORE, M.D., ST. LOUIS, MISSOURI

From The Edward Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis

The literature on Paget's disease is extensive. Moore in 1923 found 287 articles. Since that time 627 have been published, making a total of 914. In spite of this great volume of literature, the disease remains an etiological puzzle. In 1874 Schmidt described a case to which he applied the term "ostitis deformans", a term originally suggested by Czerny. Paget's article appeared in 1877, and very little has been added since then to his description of the clinical course of the disease.

Knowledge of this disorder may be divided into that of the preroentgen and the postroentgen era. The roentgenographic aspects of Paget's disease, together with some rather minor observations and the contributions of biochemistry, are about the only additions to our knowledge since Paget's time. The majority of the published articles are either reports of single cases or of small groups of cases, usually describing an existing complication or one due to Paget's disease. The largest series reported is that of Dickson, Camp and Ghormley. They collected 367 examples of osteitis deformans. It is natural that the greatest number of reports should have been published since the advent of the roentgen ray. Indeed, no article

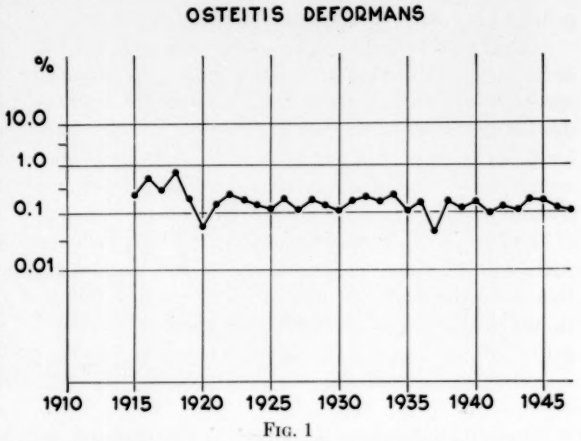


FIG. 1

Curve of incidence of osteitis deformans in 32,654 pathological conditions of the skeleton.

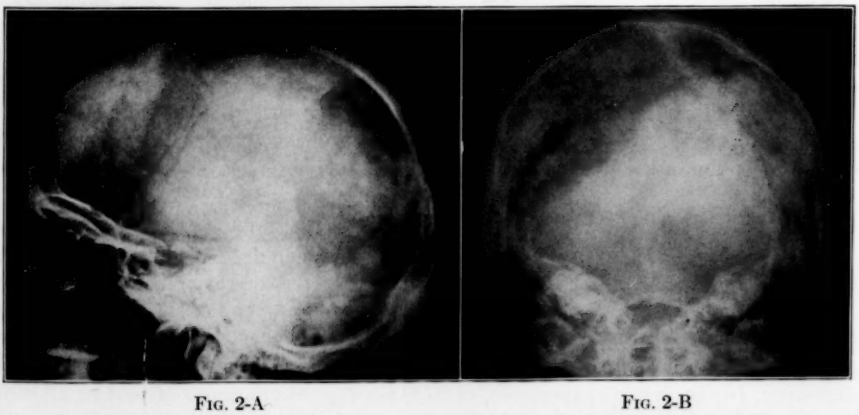


FIG. 2-A

FIG. 2-B

A patient with deafness. No changes in the temporal bone are demonstrated. The rarefying and condensing changes are largely confined to the parietal bone. Increased volume of bone has not occurred.

FIG. 3

FIG. 4

Fig. 3: Enormous thickening of the vault of the skull. Note invagination of the base of the skull and platybasia. Fig. 4: Ossifying fibroma of the skull.

on the subject can be considered complete in the absence of a description of the roentgenographic aspects of the particular case or cases.

In the preroentgen period, diagnosis was based on the deforming features of the disorder, and was therefore confined to the advanced stages of the disease. With the widespread use of the roentgen ray, diagnoses of many, if not most, of the cases of Paget's disease are based upon findings incidental to an x-ray examination, as the disease in its incipiency is devoid of symptoms. The fully developed case of the preroentgen era can be accurately diagnosed at a glance. Less fully developed cases,—for example, the bowing of a single extremity—offer more difficulty, particularly in the case of bowing of the bones of the leg, formerly confused with, and long believed to be, a manifestation of syphilis. Although the two diseases can coexist, the Wassermann reaction has long since cleared up this confusion, and, except in the very earliest phase of Paget's disease, the roentgen ray should give a clear differentiation of these two diseases of bone. The earliest findings of Paget's disease are probably unknown because of its slow progression and lack of symptoms.

DEFINITION

Osteitis deformans is limited to the skeleton and is of unknown etiology. It has a tendency to slow but ultimate involvement of the entire skeleton. It is characterized by softening of the bone and increase in its volume, which produce deformity. The process remains stationary for periods long enough to lead some writers to report a mono-osteitic form. Possibly, the period of observation in such cases has not been long enough to establish firmly this form of the disorder. Albright and Reifenstein consider the disease to be local, in spite of the fact that they, as well as the writer, have observed a case with involvement of the entire skeleton. In the one observed by the writer, a complete autopsy was done. The disease is unsystematic in its distribution and can appear in any bone, with the possible exception of the phalanges of the feet and hands.

INCIDENCE

The true incidence of Paget's disease in the general population is unknown and probably cannot be determined because of its insidious onset. Albright and Reifenstein quote Schmorl to the effect that 3 per cent. of adults over forty have Paget's disease; they use an exclamation point after this statement. It is generally accepted that, in leading clinics and hospitals in the United States, there is one case of Paget's disease for every 10,000 admissions. In the writer's experience, of 87,899 x-ray examinations of part or all of the skeleton, 55,245 were negative and 32,654 showed a pathological condition of one sort or another. Among these were 148 cases of Paget's disease, including fifteen in the rarefying

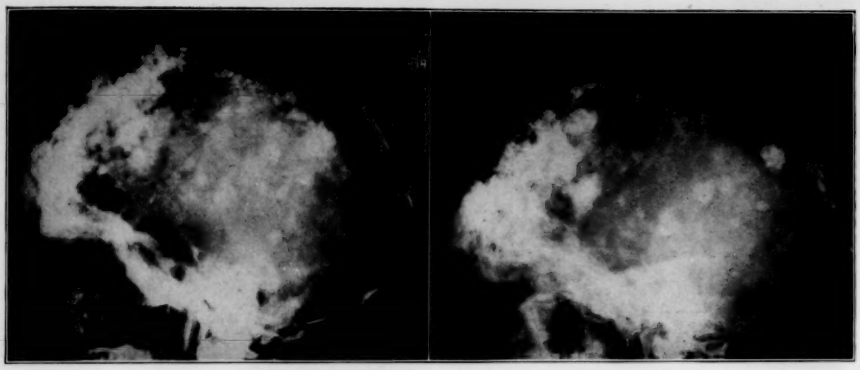


FIG. 5-A
Fig. 5-A: 1934. Osteogenic sarcoma of frontal bone.

FIG. 5-B
Fig. 5-B: 1943, shortly before death.

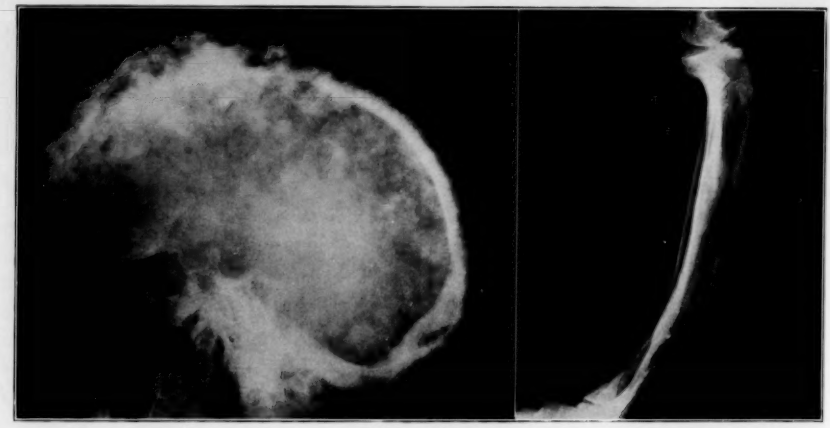


FIG. 6-A FIG. 6-B
Illustrating enormous thickening of skull and tibia, with deformity of latter. Note that fibula, not involved, follows curvature of tibia.

stage, osteoporosis circumscripta, gathered from the records of the years 1910 to 1948 inclusive. The first example of Paget's disease was recorded in 1915. The rate of occurrence in the pathological group is shown in the curve (Fig. 1). The ratio between white and colored is about that of the population in general. The disease has been reported in the young, but the juvenile cases can hardly be considered authentic by present-day standards of examination. The youngest patient in the writer's series was twenty-seven years of age. The largest number of cases, fifty-four, was found in the seventh decade. Osteitis deformans has been found in all races and in all parts of the world.

SYMPTOMATOLOGY

The symptoms of Paget's disease are so fully described in standard texts that only brief reference will be made to them. The deformity is unlike that in any other bone dystrophy. There is occasional complaint of bone pain. This is neither as severe as that in neoplastic disease, either primary or metastatic, nor of a character similar to it, or to infection. Depending upon the region involved, there can be almost any complication. The optic nerve may be compressed, causing blindness. Involvement of the temporal bone may produce symptoms of pressure on the eighth nerve (Figs. 2-A and 2-B). Trigeminal neuralgia was present in two of the writer's cases, necessitating removal of the gasserian

FIG. 7

Osteitis deformans of the radius. Note deformity of radiocarpal joint, due to lengthening of the radius.

FIG. 8

Osteogenic sarcoma with spontaneous fracture in a case of Paget's disease.

FIG. 9

Roentgenograms showing transverse fracture of tibia in osteitis deformans.

ganglion. Indeed there is no reason to suppose that any of the cranial nerves may not be affected by changes in the base of the skull. Enlargement of the maxillae and hard palate may interfere with speech, mastication, and deglutition. Involvement of the hyoid bone has been reported as affecting the voice. Spinal nerves seem to escape, but the spinal cord is sometimes compressed.

Since osteitis deformans is essentially a disease of the second half of life, it has been frequently reported in conjunction with diseases of that period, particularly cardiac and arterial disorders. Psychosis is a not infrequent complication, but no sound reason has been advanced for the belief that the Paget process has any bearing on the production of the psychosis. Though there may be enormous thickening of the bones of the skull (Fig. 3), the total capacity of the cranial cavity is not reduced, even though there may be marked invagination of the base of the skull. Hence there is no increased intracranial pressure. If there is a single localized enlargement, particularly in the case of the bones of the skull, either the vault or the visceral portion, the disease has to be differentiated from a malignant tumor,—for example, meningioma or ossifying fibroma (Fig. 4), and the rare example of osteogenic sarcoma of this portion of the skull (Figs. 5-A and 5-B). Roentgenograms usually reveal a difference in bone texture, which will establish a correct diagnosis, and, of course, in such serious conditions, if the roentgen ray fails, biopsy should be resorted to.

A word about the nature of the deformity, which does not occur in the first or rarefying stage of the disease. The involved bones increase in volume and length (Figs. 6-A and 6-B). The deformity is always opposite the greatest mass of muscle and fascia because these structures do not lengthen equally with the bone. Where one of paired bones is involved, such as those of the forearm and leg, the lengthening of one bone may deform its companion (Fig. 6-B). Both skin and subcutaneous tissue accommodate themselves to the lengthened bone. With lengthening, the bone has to bend, as has been noted by many others. In the case of the skull, the insertion of muscles on its base brings about its invagination (Fig. 3). In the lower extremity, the deformity can influence the gait. In the upper limb, function does not seem to be impaired to such an extent that great attention has been directed to it. The Pagetic process softens the bone and makes it more malleable. For this reason many believe that the deformity is produced by weight-bearing exclusively, especially in the lower extremities. However, deformities in the upper limbs have to be explained, not by weight-bearing, but by the lengthening of bones without corresponding lengthening of the muscles and fascia (Fig. 7).

SKELETAL DISTRIBUTION IN OSTEITIS DEFORMANS

Many writers tabulate the incidence of Paget's disease according to the several bones, —skull, vertebrae, tibiae, *et cetera*. It seems preferable, however, to consider it in relation to the two major anatomical divisions of the skeleton, the axial and the appendicular. The order of frequency of occurrence in the writer's view would be the lower extremity, and the pelvic girdle, the skull, vertebrae, ribs, sternum, and, much less frequently, the upper extremity with the pectoral girdle. The most distal bones of both upper and lower limbs are less often involved. From the very earliest description in the literature, increased warmth has been found over the involved bones. This phenomenon may justly be considered a symptom of the disease.

LABORATORY FINDINGS

Biopsy and blood-chemistry studies give few abnormal findings. Albright and Reifenstein find the serum calcium and phosphorus usually normal in Paget's disease, although there is a tendency for the serum phosphorous to be slightly elevated,—"the serum phosphatase level is higher per unit of bone disease in Paget's disease than in any other condition".

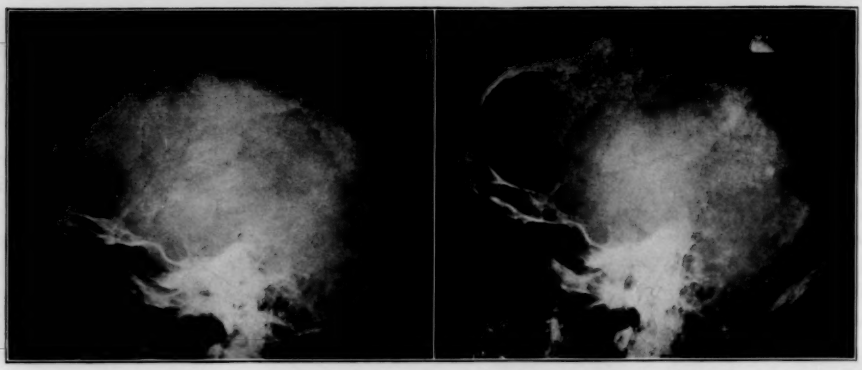


FIG. 10-A
1934. Rarefying stage of osteitis deformans.

FIG. 10-B
1943. The stage of repair is faintly seen in the occipital bone.

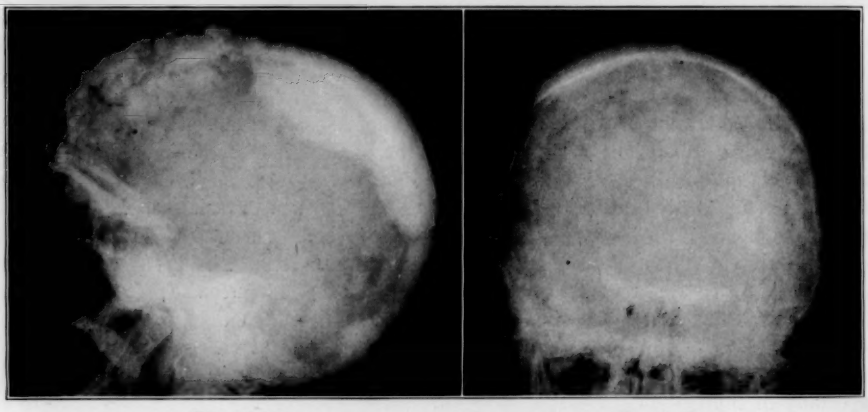


FIG. 11-A

FIG. 11-B
Marked rarefaction is best noted in the anteroposterior view. The normal bone has a clear-cut boundary. The repair process with enlargement is evident in the frontal region.

COMPLICATIONS

These are so many and so varied that only the two most common will be referred to: fracture, and the development of osteogenic sarcoma. Fracture is usually produced by slight violence. If truly spontaneous, coexisting disease should be sought for; of first importance in this respect is osteogenic sarcoma (Fig. 8). Fracture of the long bones is generally transverse (Fig. 9). Healing of Pagetic bone from either fracture or surgical operation is rapid. Indeed, at times repair seems to occur more rapidly than it does in normal bone.

CAUSE OF OSTEITIS DEFORMANS

The disorder is neither neoplastic nor infectious. Its long duration effectively removes it from the neoplastic group of diseases. In view of the Wassermann reaction, syphilis can be eliminated as a cause, and it seems safe to assume that no type of infection can produce it. Geographic, climatic, racial, hereditary, dietary, and endocrine influences do not seem to play a part in the etiology, as is so frequently the case in other disorders, especially the dietary factor in affections of the skeleton. Some writers believe that it is at times familial. The disease is unknown in domestic animals but has been described in monkeys, and Orr claims to have noted "a condition resembling Paget's disease" in rabbits. The literature

fails to reveal an example of the condition produced experimentally. The irregular distribution of the disease readily eliminates it from conditions or diseases which involve the skeleton generally and systematically.

PATHOLOGY

The gross pathological specimen of the bone shows deformity, a smooth outline without either defects or outgrowths. The bone is softer than normal and saws readily. The histological appearance has rightly been described as "chaotic". Side by side there are bone resorption and bone repair. This is to be expected in view of the two distinct phases of the disease often seen in the roentgenogram (Figs. 10-A and 10-B), the first a rarefaction and loss of mineral content with marked porosity and no enlargement; the second phase that of repair, in which there are areas of increased bone density and enlargement, and some tendency to approximate the appearance of normal bone (Figs. 11-A and 11-B). In the long bones, the rarefying process can approach that of cyst formation.

TREATMENT

Therapeutic measures which have been employed in the treatment of osteitis deformans are many, varied, and unsuccessful, so much so that it can be said that there is no

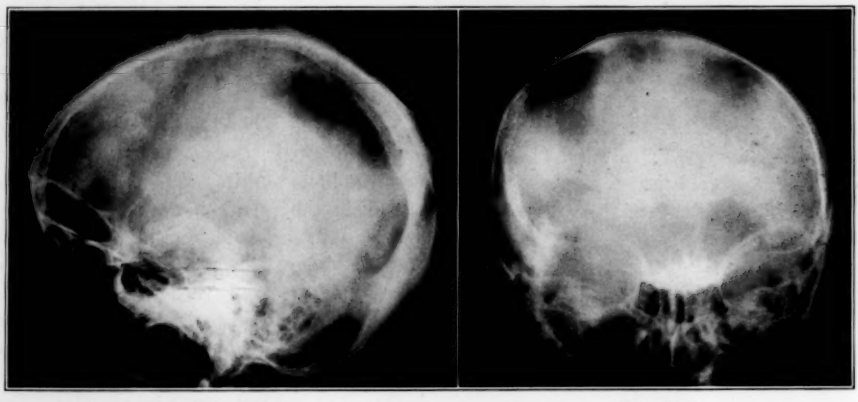


FIG. 12-A FIG. 12-B

Showing symmetrical thinning of parietal bone.

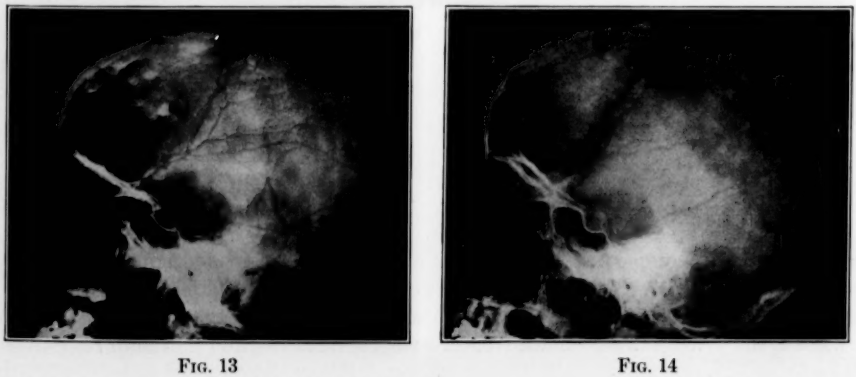


FIG. 13 FIG. 14

Fig. 13: Example of hyperostosis frontalis interna.
Fig. 14: Marked rarefaction of bones of skull without enlargement. Note sharply defined edge of normal bone with the second stage just beginning. Contrast with Fig. 13.

treatment of osteitis deformans *per se*. Deformity, when severe, can be corrected surgically. Accompanying complications call for special treatment of the structure involved.

PROGNOSIS

Prognosis as to life is good. Depending upon the extent and intensity of the process, the prognosis is determined by the special complications present,—for example, optic-nerve and spinal-cord compression. The latter is especially ominous.

DIAGNOSTIC FEATURES OF OSTEITIS DEFORMANS

FIG. 15

Osteitis deformans in male, twenty-seven years old. The defect shown was due to biopsy.

These have been so well described that they do not need to be emphasized. In the earliest phase, rarefaction may cause difficulty in reaching a conclusion. The rarefied phase can be simulated by loss of overlying soft tissue (the writer has made this mistake). A possible source of error in the case of the vault of the skull is that of symmetrical thinning of the parietal bone (hypoplasia of the diploë) (Figs. 12-A and 12-B), especially in the rare cases in which this is unilateral. However, if the x-ray fails, palpation will reveal the ridge of the adjacent normal bone.

In the second stage of the disease, that of repair, the coarse striated texture of the bone and its mottling is unlike that seen in the roentgenograms of any other disease. There is also an increased volume of the bone. The roentgenogram will occasionally reveal the beginning of the deformity when it might escape detection on physical examination. In the vault of the skull, both hyperostosis frontalis interna (Fig. 13) and hyperostosis calvariae diffusa can be confused with Paget's disease. The writer has made this error several times.

COURSE OF THE DISEASE

Paget observed his patient for twenty years, through the period of increasing deformity and resultant enfeeblement and disability. In Paget's case, there were periods when the process seemed arrested. The disease is never bilaterally symmetrical, either in extent or in intensity. It can involve any or many bones, or be confined to a single bone or a single portion of any bone for long periods. The phalanges seem to be the only unaffected portions of the skeleton. Patients do not die of the disease but from complications. Metastatic malignant disease of the skeleton is a not infrequent accompaniment. Kolodny is authority for the statement that 5 per cent. of the examples of osteogenic sarcoma in the Registry of Bone Sarcoma arose in Paget's disease. He quotes Codman as saying that 14 per cent. of the patients with Paget's disease have osteogenic sarcoma. This lesion occurred in three of the writer's cases,—in the frontal bone, the humerus, and the femur respectively.

THE CIRCULATION IN OSTEITIS DEFORMANS

In advanced cases, arteriosclerosis and cardiac disease are almost constantly present.

Many writers have noted the great enlargement of the temporal arteries, when the skull was affected. In operations on Pagetic bone, surgeons have encountered marked and troublesome vascularity, as in the writer's two patients who had operations on the gasserian ganglion. Moore in 1923 measured the volume flow of blood in a case of Paget's disease of one tibia (mono-osteitic). This was found to be 2.48 times greater than that of the normal limb. Klippel and Pierre-Weil in 1909, in a similar case, found the surface temperature averaging 5 degrees centigrade higher over the involved limb than over the corresponding portion of the opposite limb, which was normal. Moore in 1923 in a similar case (the one with increased volume flow of blood) found a difference of 4 degrees centigrade on the involved side. Snapper, in 1943, made identical observations in four cases. In these, the minimum increase was 1.5 degrees centigrade and the maximum was 3.8 degrees centigrade, with an average of 2.4 degrees centigrade for the four cases. More recently, in 1949, the writer found a difference of 2.4 degrees centigrade in an additional case (Fig. 15). In 1945 Edholm, Howarth and McMichael measured the volume flow of blood to normal bone and that to Pagetic bone. They found that it was up to twenty times greater in the latter than in the former. With involvement of a single bone they noted no cardiac symptoms. In a case of generalized Paget's disease, there were signs of congestive heart failure. "There were phenomena comparable with free arterio-venous communications suggesting that this raised output might be due to increased vascularity in the affected bones." These several observations firmly establish the fact that there is a close relationship between Paget's disease and disturbances of the circulation. Does Paget's disease produce the circulatory phenomenon, or does the circulation bring about Paget's disease? Which is cause and which is effect? In view of the fact that widespread disease or injury of the skeleton, trauma, osteitis fibrosa cystica, hyperparathyroidism, and particularly metastatic skeletal carcinosis have little or no repercussion in the circulation, it must be considered that there is a circulatory factor in the production of osteitis deformans; when the disease is widespread, the heart itself will suffer, as shown by Edholm, Howarth, and McMichael.

Disease of the nervous system may profoundly affect the skeleton,—for example, tabes dorsalis, syringomyelia, and poliomyelitis (in development and atrophy). Likewise, anaesthetic leprosy destroys bone. However, none of these conditions has any circulatory manifestations of consequence.

AN HYPOTHESIS AS TO THE ETIOLOGY OF OSTEITIS DEFORMANS

It is clear that the blood circulation in bone is profoundly altered in Paget's disease. A cause for the increased vascularity must be sought for. The autonomic nervous system controls the blood vessels, increasing or decreasing the volume flow of blood, subject to various influences.

It is proposed that disorder, either organic or functional, of the autonomic nervous system brings about the increased vascularity of the bone in osteitis deformans. This theory can account for the increased volume flow of blood of the involved bone, the stage of bone resorption, the stage of bone repair, the increased growth of bone, and also the local thermogenesis, which is the product of heightened metabolic exchange. In no other way can the phenomena of osteitis deformans be explained. It is, therefore, proposed that osteitis deformans is actually due to sporadic failure of the autonomic nervous system and is not a disease of bone. However, this does not explain the absence of comparable changes in the adjacent soft tissues.

REFERENCES

1. Albright, Fuller, and Reifenstein, E. C.: The Parathyroid Glands and Metabolic Bone Disease, 284–301. Baltimore, The Williams and Wilkins Company, 1948.
2. Dickson, D. D., Camp, J. D., and Ghormley, R. K.: Osteitis Deformans: Paget's Disease of the Bone. Radiology **44**: 449–470, 1945.

3. Edholm, O. G., Howarth, Sheila, and McMichael, J.: Heart Failure and Bone Blood Flow in Osteitis Deformans. Clin. Sc. **5**: 249–260, 1945.
4. Klippel, M. and Pierre-Weil, M.: A propos d'un cas d'ostéité déformante. La pathogénie de la maladie osseuse de Paget. *In* Nouvelle Iconographie de la Salpêtrière, **22**: 1–23, 1909.
5. Kolodny, Anatole: Bone Sarcoma, p. 71. Chicago, Surgical Pub. Co., 1927.
6. Moore, Sherwood: Observations on Osteitis Deformans. Am. J. Roentgenol., **10**: 507–518, 1923.
7. Orr, John W.: Osteoporosis in a Rabbit with Osseous Changes Resembling Paget's Disease. J. Path. and Bact., **45**: 29–33, 1937.
8. Paget, James: On a Form of Chronic Inflammation of Bones (Osteitis Deformans). Medico-Chir. Trans. London, **60**: 37–63, 1877.
9. Schmidt, Benno: Ein Fall von Ostitis deformans. Arch. d. Heilkunde, **15**: 81–82, 1874.
10. Snapper, I.: Medical Clinics on Bone Diseases, 131–150. New York, Interscience Publishers, 1943.

FIXATION OF SMALL BUT IMPORTANT BONE FRAGMENTS WITH A HOOK PLATE

BY LIEUTENANT COLONEL WILHELM A. ZUELZER, *Medical Corps, United States Army*

The preliminary report of the method of fixing small bone fragments with the help of a hook plate was published in 1948 [1]. A more extensive report can now be made.

It is well known that not all fractures can be reduced and held properly by closed methods. This is particularly true of fractures which involve part of a joint, where accuracy is the keystone of success. Delay of treatment, necessitated by clinical reasons or other circumstances, will add to the difficulties of obtaining and maintaining a satisfactory reduction.

Shaft fractures of the long bones, presenting a different problem, have been the subject of many articles. In addition to the basic procedure of conservative treatment with immobilization alone or with skin or skeletal traction, many ingenious devices for fixation have been reported.

In a large orthopaedic hospital, receiving a considerable number of fracture cases, it was decided to try the use of a hook plate in order to simplify the procedure of an open reduction and to get consistently solid fixation. Direct screw fixation, often used in fractures of the medial malleolus, has the disadvantages of requiring an incision over the entire joint for the exposure of the lower pole of the fragment, with possible damage to the blood supply; of the possible splitting into small fragments or of damaging the osteogenic cancellous portion; of the inability of fixing several small fragments; and of the difficult placing of the screw in correct position, without encroaching on the joint cartilage. Wire fixation and periosteal sutures have similar disadvantages.

Any successful fixation method must meet the following requirements:

1. The surgical procedure should not be complicated;

2. A minimum amount of metal for fixation should be used;

3. Solid fixation of the small but important bone fragments should be obtained in such a manner that future displacement, even under tension, is made impossible;

4. Splitting of the fragment should be avoided.

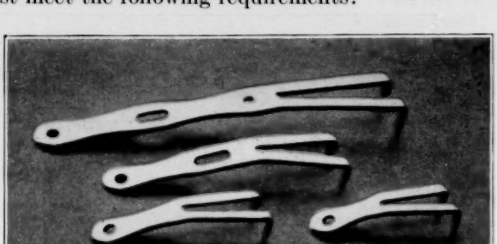


FIG. 1

It is recognized that the best functional results will be obtained in fractures of the joints if anatomical reduction is obtained and maintained, for this will encourage early bony union and allow early mobilization.

The hook plate seemed to meet these criteria. It has been used successfully in fifty-seven cases:

Medial malleolus fractures	50
Medial malleolus fractures including part of the epiphysis of the lower part of the tibia	2
Fractures of the lower end of the tibia (comminuted)	2
Fractures of the lateral condyle of the tibia	2
Olecranon fracture with severe comminution	1

DESCRIPTION OF THE HOOK PLATE

The first hook plate was made from a Lane plate in our own orthopaedic workshop. One half of the plate was split longitudinally at the midline, and two prongs were obtained, with short hooks at their ends (Fig. 1). Since that time, different sizes have been made, starting with an over-all length of 2.80 centimeters and increasing gradually up to 10 centimeters, with one, two, or three holes in the plate part. If the plate is made with more than one hole, one of these may be changed into a slot to allow for further impaction after the first screw is placed. The entire hook plate can be bent with a pair of pliers to conform to the contour of the bone. Of course, the same metal, with a minimum of electrolytic action, must be used for both plate and screws.

SURGICAL TECHNIQUE

No great problems will be encountered in using the hook plate. After a hairline reduction has been accomplished, the hook plate is applied subperiosteally along the bone and shaped to the contour of the bone. Only the prong-hook part will cover the small fragment, while the hooks themselves will be introduced into holes made with a short Kirschner wire. One must be careful to avoid impaction of the hooks into the fragment without first establishing the holes, since the hooks will usually straighten out and not penetrate the bone. The hooks should never enter the joint itself; their length must, therefore, be adjusted by cutting off the part not needed with a pair of pliers. The last step at operation is the drilling of a hole for the screw which is applied in the usual way. In malleolus fractures it has been found that one short screw will suffice, penetrating only one cortex. For tibial, condylar, and olecranon fractures, two or three screws are advisable. In these latter fractures, careful consideration must be given in each individual case as to whether or not the opposite cortex should also be engaged by the screw. In these cases, a slot is often more valuable than a hole, because it allows further impaction after one screw has been applied.

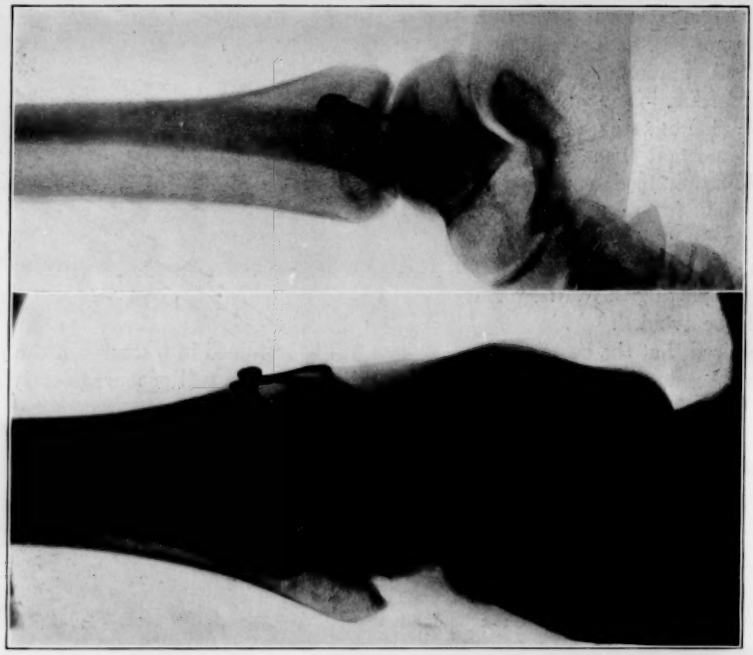


FIG. 2-B

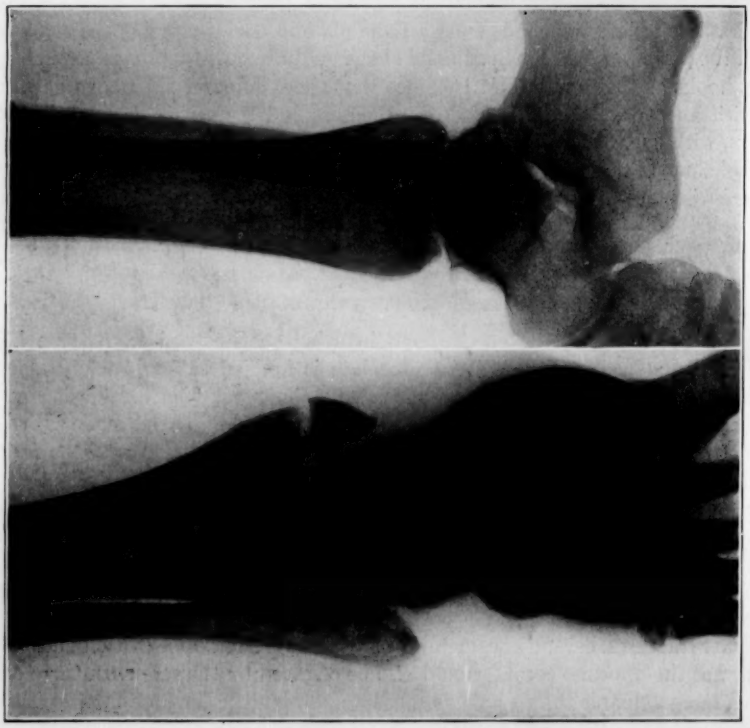


FIG. 2-A

A typical case of fracture of the medial malleolus, treated by hook-plate fixation.

In all cases, the surgeon has the advantage of keeping the fragments reduced by applying the plate and the screw to healthy cortical bone away from the fracture site. The possibility of future distraction (one of the most common causes of non-union) is

FIG. 3-A

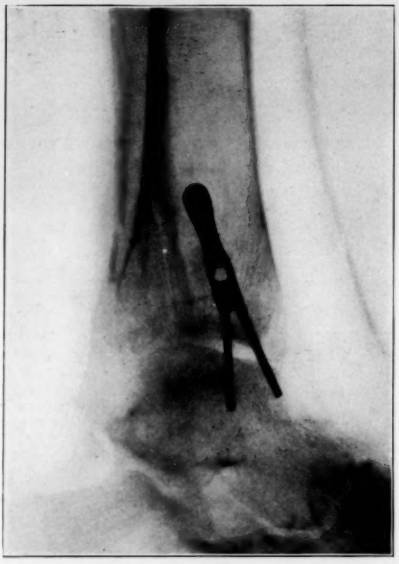


FIG. 3-B

The fragment of a medial malleolus, split during direct screw fixation, is held by the grasping action of the hook plate. The hook plate was later removed.

FIG. 4-A

FIG. 4-B

An unusual case of severe comminution of a fractured medial malleolus, treated by hook-plate fixation.

FIG. 5-C

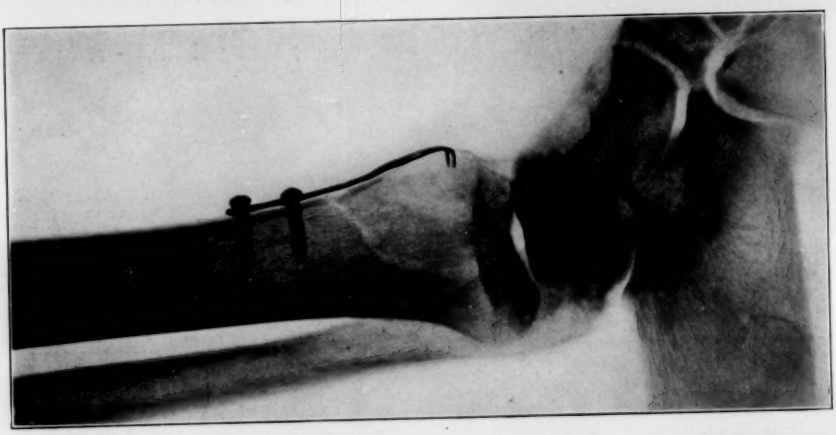


FIG. 5-B
After open reduction and hook-plate fixation.

FIG. 5-A
A comminuted fracture of the lower end of the tibia.

FIG. 6-A

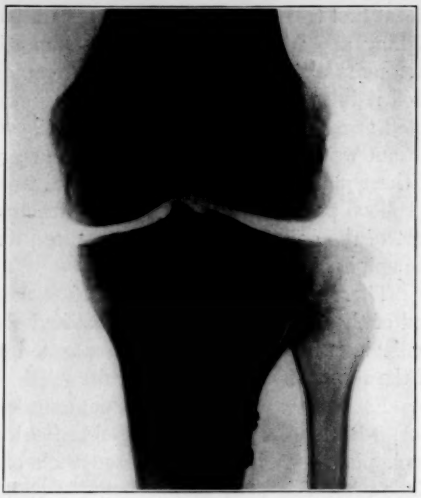


FIG. 6-B

A depressed fracture of the lateral condyle of the tibia before and after open reduction and hook-plate fixation.

FIG. 7-A

FIG. 7-B

A severely comminuted olecranon fracture before and after hook-plate fixation.

eliminated, for the fragments remain pressed against one another. Following the open reduction, a plaster-of-Paris cast is always applied.

In fractures of the medial malleolus it was found that usually only one screw was needed, penetrating only one cortex. Roentgenograms (Figs. 2-A and 2-B; 4-A and 4-B) which clearly indicate the method of fixation, show that a minimum amount of metal covers the fragment on its outer aspect. In forty-seven patients with fractures of the medial malleolus, excellent results were obtained and the men were able to resume normal activities within a reasonable amount of time. In none of these patients was there indication for the removal of the hook plate. In one, however, the plate was removed because it caused local tenderness; this was done eight weeks after open reduction, and after union had taken place. In one patient, non-union resulted for the hooks did not engage the distal fragment and reduction of the fracture could not be maintained. One fracture

was at first treated with direct screw fixation; the fragment was broken into several pieces, making any further screw fixation impossible. When the hook plate was applied, the fragments were held in place by the grasping action of the hooks (Figs. 3-A and 3-B) and good reduction was maintained. Because the hooks were too close to the joint itself and acted as a local irritant, the hook plate was removed nine weeks after reduction. In no patient was there a breakdown of the overlying skin. It is interesting to note that most of these patients were soldiers who had to return to field duty.

Two patients in this series had fractures of the medial malleolus which involved a part of the epiphysis. In these fractures, fixation was easily obtained without disturbing the epiphyses.

There were two patients with fractures of the medial malleolus in which the distal end of the tibia at the lateral aspect had also been fractured. After fixation of the medial malleolus with the hook plate, a separate incision was made for the reduction and fixation of the second fragment of the tibia.

Each of two patients had a comminuted fracture of the lower end of the tibia (Figs. 5-A, 5-B, and 5-C). After an open reduction, the two major fragments were fixed by the hook plate,—each fragment fixed with one hook. The smaller fragments remained in place after this type of fixation. No claim is made that good functional results were obtained. Neither patient could be followed beyond the hospital period.

Fractures of the lateral condyle of the tibia were found in two patients (Figs. 6-A and 6-B). In these cases it was felt that the small but important fragment would be solidly fixed with the help of a hook plate, since the hook plate presses the fragment firmly into its bed. If there is considerable shearing force exerted upon the fragment, two or three screws, which should also engage the opposite cortex, should give sufficient protection from recurrence of displacement. If the fracture is comminuted, the two major fragments should be held in place, each with the aid of one hook.

One patient had a severely comminuted simple fracture of the olecranon (Figs. 7-A and 7-B). In this case the proximal fragment was under continuous tension of the triceps muscle. Removing all the fragments would have resulted in a flail elbow joint; therefore, since the small proximal fragment would not allow an intramedullary nail, plate, or wire fixation, the hook plate was applied with the plate portion solidly attached to the healthy cortical bone of the shaft of the ulna. In that position it held the proximal fragment securely and allowed replacement of the comminuted part, which, in turn, was held by two additional wires. After ten weeks this man had motion of from 90 to 130 degrees.

COMMENT

The hook plate is a simple appliance, and it can be made available at a minmum cost. It has proved to be of value for the internal fixation of small, bony fragments which have an important function and cannot be discarded.

No claim is made that bony union and an excellent functional result can be expected in all cases. But it is felt that it offers a sound method of reliable internal fixation. It should be clearly understood that, in most cases, regular plaster-of-Paris cast fixation was used till bony union was obtained. The final result depended, of course, on the type of fracture and the amount of joint destruction, not to mention the many other factors which enter into each individual case. The earlier bony union is obtained, the earlier is it possible to start mobilization and functional stimuli by normal use, and the better are the chances for a good functional result.

NOTE: The kind, constructive criticism and encouragement given by F. C. Bost, M.D., J. E. Milgram, M.D., R. S. Reich, M.D., and Col. J. Blair is gratefully acknowledged.

1. ZUELZER, W. A.: An Indirect Method of Fixation of Small Fractured Fragments with the Help of a Hook-Plate. The Medical Bulletin of the European Command, **5**: 16–20, 1948.

AN IMPROVED TYPE OF ARTHROPLASTY OF THE HIP JOINT

BY ANTHONY F. DEPALMA, M.D., PHILADELPHIA, PENNSYLVANIA

From the Department of Orthopaedic Surgery, Jefferson Hospital, Philadelphia

The reconstruction procedure described in this article was designed primarily for cases of absorption of the neck of the femur following non-union. However, the results have proved so gratifying that the method is now employed in cases demonstrating other pathological lesions of the hip joint, where hitherto a Vitallium-cup arthroplasty, such as that described by Smith-Petersen, had been considered necessary. This procedure was designed because the various types of arthroplasties and hip reconstructions most commonly performed fall short of the goal aimed for by the surgeon, — namely, to give the patient a stable and painless hip with a good range of free motion and at the same time to reconstruct a hip joint approaching closely the anatomical architecture of a normal joint.

Essentially, the operation comprises removal of the head and neck of the femur, severing all muscle attachments from the greater trochanter, osteotomizing the shaft of the femur four inches (10 centimeters) from the top of the greater trochanter, tilting the upper fragment medially to restore the normal angle of the neck of the femur (about 135 degrees); and fixing the fragments in this position by a Neufeld nail. The greater trochanter is then covered with a Vitallium cup and placed in the acetabulum. Finally, with the extremity slightly abducted, the glutaeus medius and glutaeus minimus are reattached through drill holes to the lateral aspect of the distal end of the proximal fragment. This procedure, by providing a normal angle between the new neck and shaft of the femur, produces a joint approaching closely the architecture of the unaffected hip joint; furthermore, since the abductor muscles are transplanted downward, the efficiency of this group of muscles is not impaired seriously.

OPERATIVE PROCEDURE

1. Exposure is achieved by a double curved incision which begins one inch (2.5 centimeters) lateral to the anterior superior spine of the ilium; it continues downward along the lateral aspect of the thigh for a distance of seven inches (17.5 centimeters) below the base of the greater trochanter, and then curves posteriorly for three inches (7.5 centimeters) (Fig. 1, *A*). The interval between the glutaeus medius and the tensor fasciae femoris is enlarged, thereby exposing the anterosuperior aspect of the articular capsule of the hip joint. The iliotibial band is split longitudinally as far as the end of the upper arm of the skin incision, and then is divided transversely in the line of the lower curved arm of the skin incision. This allows adequate mobilization of the posterior flap of the incision, which, when retracted laterally, brings into view the upper portion of the vastus lateralis and the greater trochanter, as far proximally as the tip (Fig. 1, *B*).

2. The muscle attachments (glutaeus medius and glutaeus minimus) to the greater trochanter are divided close to their insertion into the bone. This step facilitates removal of the head fragment by mobilizing the upper end of the femur.

3. The capsule is incised longitudinally and as much as is accessible is excised. This makes possible visualization of the head and neck of the femur, and the pseudarthrosis is identified. With an osteotome or a small curette, the pseudarthrosis is cleared away, thereby mobilizing the head and permitting the shaft of the femur to be rotated externally. By sharp dissection, all fibrous tissue is cut away from the neck and distal surface of the femoral head. The head of the femur is then ready to be removed from the acetabulum. This can be facilitated by the use of doubly curved gauges, inserted between the articular surfaces of the acetabulum and femoral head and employed as levers to pry the

head out of the socket. Occasionally it may be necessary to divide the head into several fragments with a thin osteotome before it can be removed. The remaining portion of the neck is cut close to the shaft; all loose particles of bone are extracted.

In cases of osteo-arthritis, the hip is first dislocated and then the head and neck are removed with a thin osteotome. The surgeon cuts through the base of the femoral neck, close to the shaft of the femur, leaving a smooth surface.

4. Next, the upper end of the femur must be mobilized completely. This is accomplished readily by grasping the greater trochanter with a large bone forceps, displacing it upward and outward out of the wound, and dividing the short external rotator muscles close to their insertion into the femur. This group includes the piriformis, gemelli, external and internal obturators, and quadratus femoris. In addition, the remaining posterior portion of the articular capsule is severed. The upper end of the femur is brought out of the wound and its trochanteric end is rounded off with large rongeurs. A loosely fitting, but not overlarge, Vitallium cup is then placed over the remodeled end of the femur.

5. At a point four inches (10 centimeters) below the tip of the trochanter, the vastus lateralis is split down to the bone for an inch in both the proximal and distal directions, and the entire circumference of the shaft of the femur is exposed by sharp subperiosteal

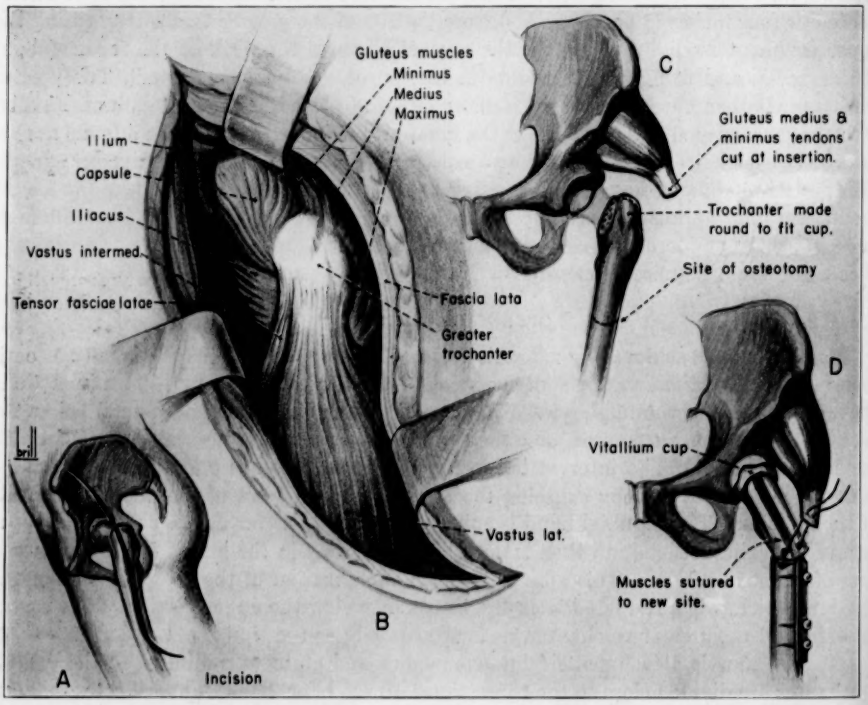


FIG. 1

A: Skin incision.

B: Interval between tensor fasciae femoris and glutaeus muscle is widened, to expose the articular capsule. The fascia lata is split longitudinally to the end of the upper arm of the incision, and then severed transversely in line with the lower arm of the incision.

C: Shows removal of head and remaining fragments of the neck of the femur, line of severance of the muscle attachments into the greater tuberosity, and site of transverse osteotomy of the shaft of the femur, four inches below the tip of the greater trochanter.

D: Vitallium cup has been fitted over the trochanteric surface, and the femoral fragments fixed in the desired position by a Neufeld nail. The end of the trochanter is then placed in the acetabulum. Note that the angle of the upper femoral fragment to the lower one conforms to the angle of the nail (135 degrees). The abductor muscles are reattached through two drill holes to the distal end of the proximal fragment along its lateral surface.

dissection. The shaft is then divided transversely, four inches (10 centimeters) from the tip of the greater trochanter, by a Gigli saw.

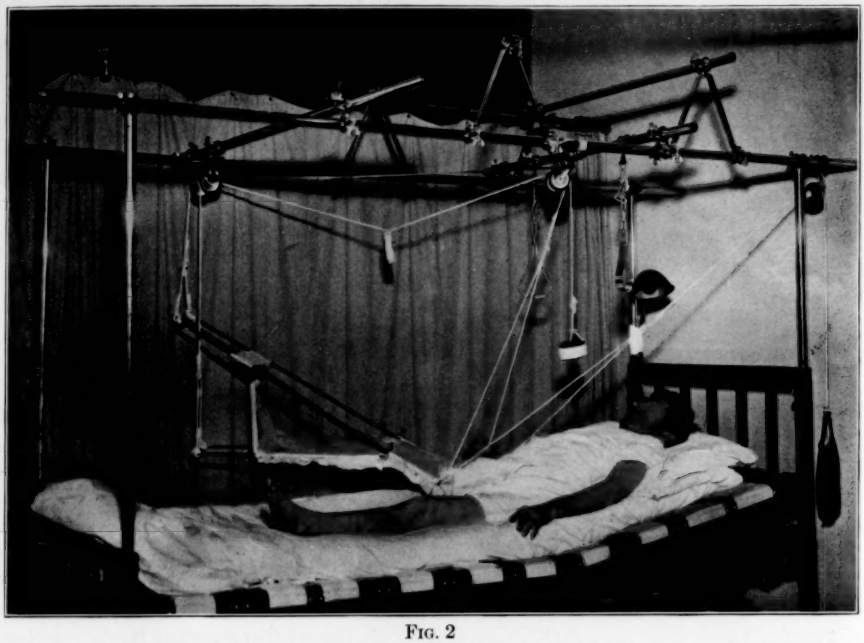


FIG. 2

The extremity is placed in balanced-suspension apparatus immediately after operation.

FIG. 3-A

FIG. 3-B

Fig. 3-A: Osteo-arthritis of right hip in H. W., a woman, aged thirty-four years.
Fig. 3-B: February 20, 1947. Roentgenogram taken immediately after operation. A Vitallium cup was not employed.

6. A Neufeld nail, three and one-half inches long, is driven into the medullary canal of the proximal fragment at an angle of 135 degrees. While an assistant holds the ex-

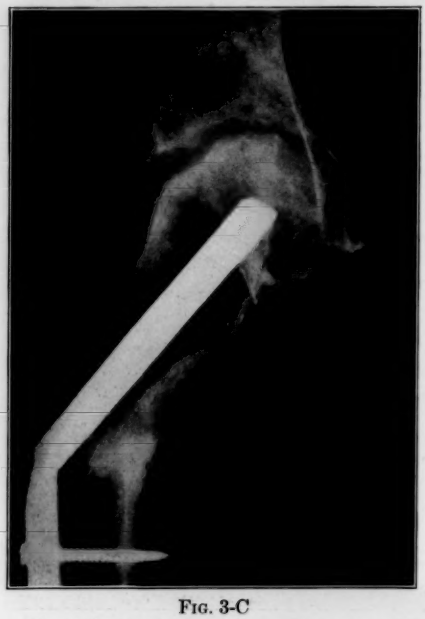


FIG. 3-C

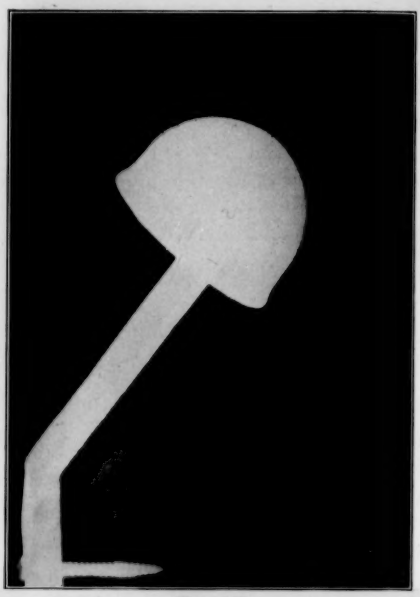


FIG. 3-D

Fig. 3-C: May 6, 1948. Bony union was complete fifteen months after operation. However, patient had pain in groin and knee and marked restriction of motion.

Fig. 3-D: September 16, 1949, sixteen months after a Vitallium cup had been placed between the acetabulum and the trochanteric surface. Note the solid bony union at the osteotomy site. The relation of the proximal to the distal fragment depicted in this case is the ideal position to strive for.

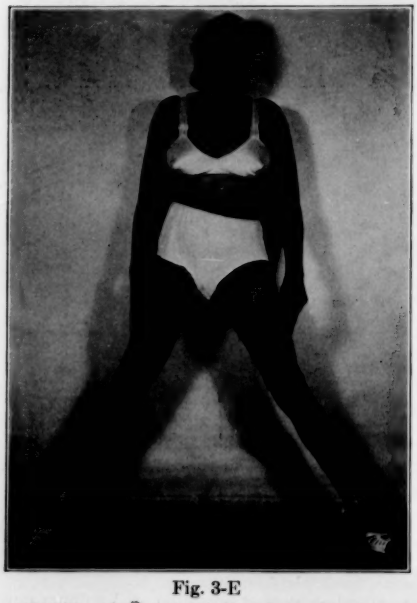


Fig. 3-E

Shows amount of abduction when patient is standing.

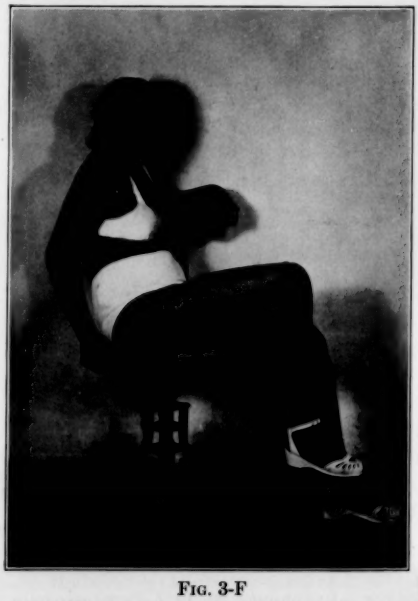


FIG. 3-F

Amount of flexion at hip possible in sitting position.

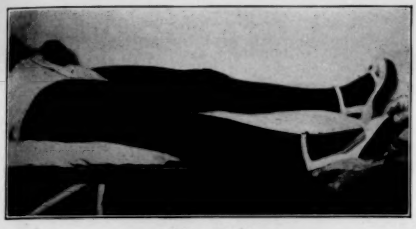


FIG. 3-G
Abduction and internal rotation of the hip.

FIG. 3-H
Abduction and external rotation of the hip.

tremity so that the toes and patella point straight upward, the distal arm of the nail is anchored to the shaft of the lower fragment by three Townsend and Gilfillan screws. The proximal fragment should be held in the true coronal plane of the body while the lower arm of the Neufeld nail is being attached to the lower femoral fragment. This eliminates anteversion of the upper fragment in relation to the lower one, thereby preventing dislocation of the femur when the extremity is externally rotated. Conforming to the angle of the Neufeld nail, the proximal fragment forms an angle of 135 degrees with the distal one, hence re-establishing the normal femoral-neck angle.

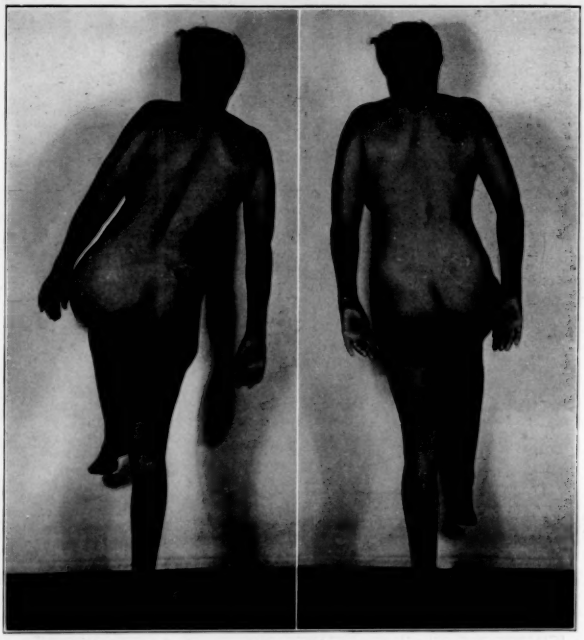


FIG. 3-I
Fig. 3-I: Although the Trendelenburg test is moderately positive, patient's gait is free and painless. The upper fragment is in the desired position relative to the distal fragment. (See Fig. 3-D).

7. While an assistant exerts traction on the limb, the end of the femur is guided into the acetabulum with the aid of a bone skid. Once the head is in the acetabulum, stability of the joint is ensured by placing the extremity in 45 to 60 degrees of abduction and complete extension.

8. The abductor muscles (glutaeus medius and glutaeus minimus) are next attached to the distal end of the lateral aspect of the proximal fragment by stout silk sutures, passed through two drill holes in the outer cortex. The edges of the vastus lateralis are sutured over the abductors to prevent these muscles from pulling away from their point of insertion. During closure of the wound, the extremity is held at all times in a position of 45 to 60 degrees of abduction.

POSTOPERATIVE CARE

If all the details of the procedure have been meticulously carried out, the stability of the hip will be such that no plaster fixation is needed. The extremity is placed in an

FIG. 4-A

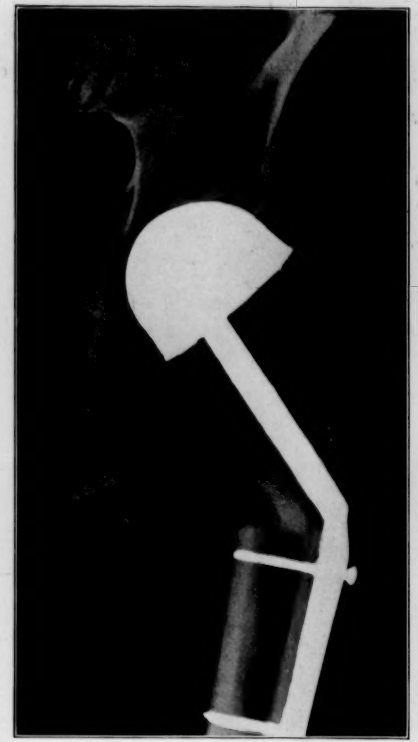


FIG. 4-B

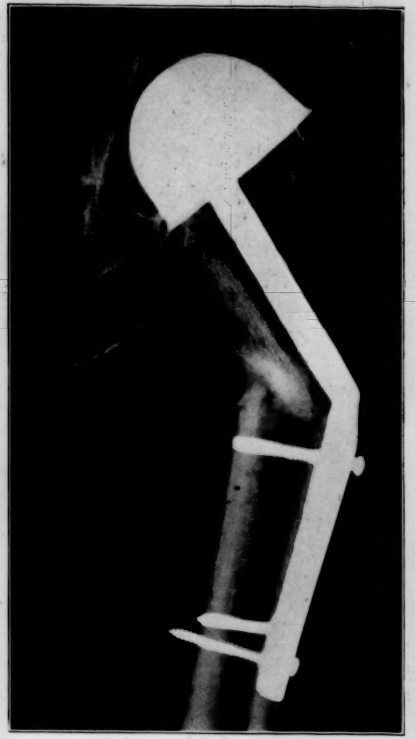


FIG. 4-C

Fig. 4-A: September 1, 1948. N. I., aged sixty-seven years, had non-union with absorption of a portion of the left femoral neck.

Fig. 4-B: December 30, 1948. Postoperative status of new hip, four months after operation. The upper femoral fragment is in a few degrees of varus in relation to the lower fragment (Compare with Fig. 1). This amount of varus deformity is of no significance.

Fig. 4-C: Status of new hip joint on July 1, 1949, ten months after operation, showing solid bony union. There has been no further diminution of the new femoral angle. When last seen on June 3, 1950 (twenty-one months after operation), the patient's hip joint was excellent.

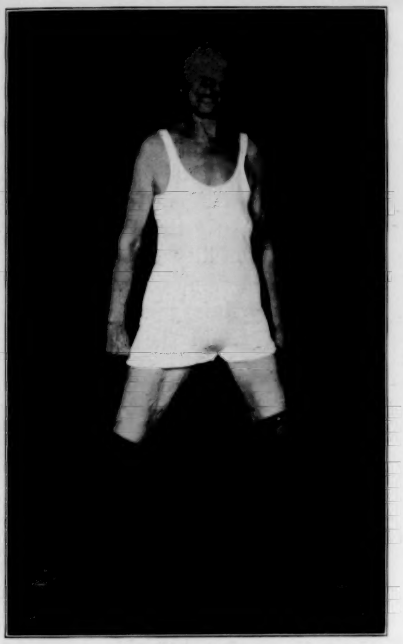


FIG. 4-D

Shows amount of abduction when patient is standing.

FIG. 4-E

Amount of flexion at hip in sitting position.

FIG. 4-F

Abduction and internal rotation of the hip.

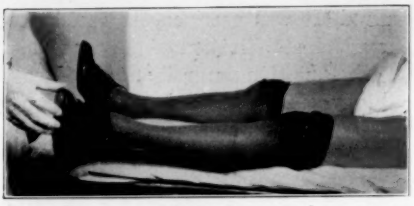


FIG. 4-G

Abduction and external rotation of the hip.

apparatus to hold it in balanced suspension (Fig. 2); active motion is started on the first postoperative day. In the apparatus the extremity is flexed 25 to 30 degrees at the hip, abducted 45 degrees, and flexed 15 to 20 degrees at the knee. The toes and patella point straight upward.

As previously stated, motion at the hip and knee is started at once on a regulated schedule; physical therapy in the form of heat, massage, and quadriceps exercises is given daily. At the end of six weeks the patient is allowed up on crutches with an elevated shoe on the opposite foot and is told to swing the affected leg in all directions. No weight-bearing is allowed on the extremity until there is roentgenographic evidence of good bony union at the osteotomy site,—a period of twelve to sixteen weeks. With the return of good muscle control, the crutches are discarded in favor of a cane.

PITFALLS TO BE AVOIDED

The operation described is an extensive surgical procedure and must be undertaken only after the patient has been amply prepared. During the operation, fluids and blood

angle. When last seen on June 3, 1950 (twenty-one months after operation), the patient's hip joint was excellent.
ERY

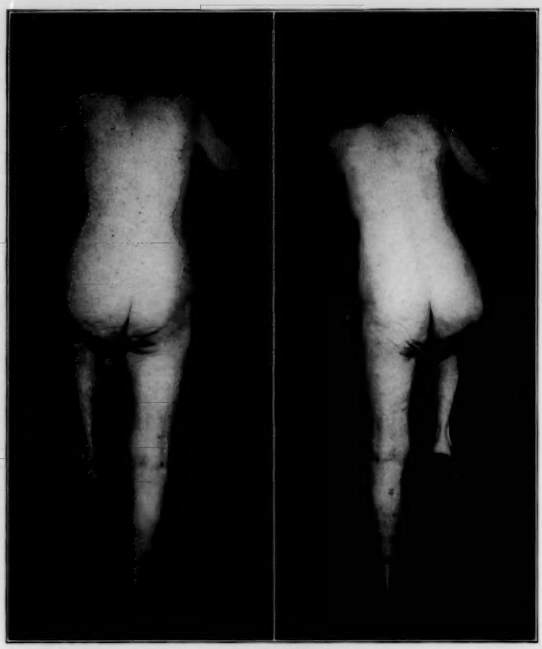


FIG. 4-H

Fig. 4-H: Patient has a negative Trendelenburg test and an excellent, painless gait. The fragments on the side of the osteotomy have united in the desired position.

should be administered, and the tissues should be handled with gentleness in order to prevent shock.

Stability of the hip depends upon the ultimate bony architecture established and the efficiency of the iliofemoral muscles, particularly the abductors of the hip. Stability can be assured if care is employed in placing the proximal fragment in a neutral position (in the coronal plane). If the fragment is fixed to the shaft in an anteverted position or directed posteriorly to the coronal plane, dislocation may take place. Such a complication occurred in one case, in which the proximal fragment was placed in slight anteversion. The dislocation was reduced readily by internal rotation of the extremity, which was then placed in plaster for six weeks. However, after the plaster fixation had been removed, dislocation of the hip recurred. It was necessary to revise the position of the proximal fragment surgically, after which stabilization of the new joint was achieved.

The question naturally arises of whether or not a Vitallium cup or mold is necessary in this type of arthroplasty. In the first two cases in which this type of arthroplasty was employed, no Vitallium cup was used. In one (Case E. M.) the amount of motion demonstrable at subsequent examinations was found to be progressively less. Two years after

TABLE I

ANALYSIS OF CASES

Case	Sex	Age	Side Affected	Preoperative Diagnosis	Date of Operation	Period after Operation (*Months*)	Result	Satisfactory To Patient	Satisfactory To Surgeon
E.M.	F.	63	Left	Non-union	Jan. 7, 1947	41	Poor	Yes	No
E.R.	F.	75	Right	Non-union	Jan. 9, 1947	41	Good	Yes	Yes
H.W.	F.	34	Right	Osteo-arthritis	Feb. 20, 1947	40	Excellent	Yes	Yes
B.B.	M.	69	Right	Non-union	Feb. 5, 1947	40	Excellent	Yes	Yes
M.G.	F.	60	Left	Osteo-arthritis	July 1, 1947	34	Good	Yes	Yes
L.M.	F.	75	Left	Non-union	July 9, 1947	34	Poor	No	No
L.M.	F.	71	Left	Non-union	Mar. 22, 1948	26	Fair	Yes	Yes
A.M.	F.	72	Left	Non-union	Apr. 27, 1948	25	Fair	Yes	Yes
J.M.	F.	82	Right	Non-union	May 17, 1948	24	Poor	No	No
R.S.	F.	80	Right	Non-union	Nov. 9, 1948	18	Poor	No	No
N.E.	F.	67	Left	Non-union	Sept. 8, 1948	20	Excellent	Yes	Yes
J.L.	M.	41	Right	Non-union	Jan. 15, 1949	16	Excellent	Yes	Yes
T.R.	M.	52	Right	Osteo-arthritis	May 3, 1949	12	Excellent	Yes	Yes

FIG. 5-A

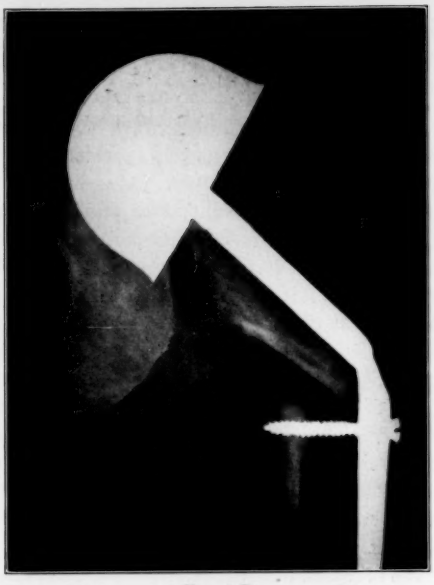


FIG. 5-B

Fig. 5-A: March 23, 1948. Non-union of the left hip of a woman, aged seventy-one years, with absorption of the neck of the femur and death of the head. Note remains of a bone graft in trochanteric region, inserted at another hospital, which failed to achieve union.

Fig. 5-B: April 21, 1948. Status of newly reconstructed hip joint, one month after operation. The upper fragment is in the ideal position in relation to the lower one.

Fig. 5-C: January 20, 1949. Solid bony union, nine months after operation. There is a slight decrease in the femoral angle, when compared with Fig. 5-B. When last examined on May 20, 1950, twenty-six months after operation, this patient's result was evaluated as fair.

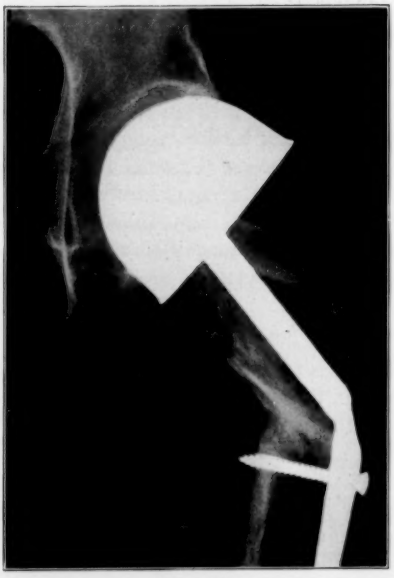


FIG. 5-C

operation, bony ankylosis had occurred. In the other patient (Case H. W.) a small amount of motion was present in the hip joint, but pain was an outstanding symptom. This patient agreed to have a Vitallium cup placed between the articular surfaces of the acetabulum and femoral head; an obturator neurectomy was also done. These procedures resulted in marked increase in motion of the joint and complete relief of pain (Figs. 3-A to 3-I). This patient has walked three miles without discomfort and uses no crutches or cane. It is apparent that a Vitallium cup or mold ensures a greater range of painless motion.

A varus position of the proximal fragment decreases the efficiency of the hip joint and produces a severe limp. Such a deformity may result from too early weight-bearing or may be the result of faulty surgical technique. In one instance the proximal fragment was fixed to the fragment of the lower shaft in a position of moderate varus at the time of operation. This patient had a stable hip, but considerable pain and a severe limp. In another, weight-bearing was permitted before solid bony union was demonstrable roent-

genographically. This patient also exhibited a severe limp and had moderate pain, radiating to the anteromedial aspect of the thigh and to the knee.

ANALYSIS OF CASES

The arthroplasty described has been performed in seventeen cases since January 1947. Only the fourteen cases in which the postoperative period has been one year or more are included in this analysis. There were three males and eleven females; their ages ranged from thirty-four to eighty-two years. No deaths were caused by the operation. One patient died eight months after the arthroplasty from an unrelated cause. Among the thirteen remaining patients, there were four poor results (Table I). One of the poor results was due to faulty surgical technique; the proximal fragment had been placed in a position of varus at the time of the operation. Varus deformity of the proximal fragment was responsible for the poor result in the second case. In this instance the deformity was caused by too early weight-bearing. Failure to place a Vitallium cup between the articular surfaces of the acetabulum and the greater trochanter resulted in the third poor result. In this instance bony ankylosis occurred, resulting in a stable and painless hip. The fourth poor result was in a patient with far-advanced Paget's disease, with marked bowing of the femur on the side on which the arthroplasty was done. Healing at the osteotomy site occurred with a severe varus deformity of the proximal fragment. This patient had pain and marked restriction of motion in the new hip joint. Evaluation of the remaining nine cases revealed that the results were excellent in five, good in two, and fair in two.

All of the patients except three of those with poor results discarded eventually all supports, such as crutches and canes. All exhibited a slight limp; this, however, did not preclude development of a good free gait, approaching the normal.

Trendelenburg Test

Six of the thirteen patients had a positive Trendelenburg test of varying degree. In those cases with considerable varus deformity of the proximal fragment, the test was markedly positive (Cases L. M., J. M., and R. S.). Seven patients (53.8 per cent.) exhibited a negative Trendelenburg test. The severity of the lurch which the patients demonstrated upon walking paralleled the degree to which the test was positive. Those with a negative test had a gait closely approaching normal. One patient (Fig. 3-D) with no varus deformity of the upper fragment had a moderately positive test, but a relatively free and painless gait.

DISCUSSION

This type of arthroplasty is an extensive surgical procedure. It should be employed only in those patients with relatively good general physical fitness, who have the willingness to cooperate fully after the operation. It is primarily designed for cases of non-union with necrosis of the head of the femur and absorption of the femoral neck. However, as previously noted, this arthroplasty has given excellent results in cases of osteo-arthritis of the hip joint; and there is reason to believe that it will give equally good results in patients with arthritis following Legg-Perthes disease, slipped femoral epiphysis, and fracture-dislocation of the hip joint.

In the experience of the writer, this type of arthroplasty has given far better results than any of the other reconstructive procedures. The reason for this is obvious: The procedure described restores the normal mechanics of the hip joint by producing a normal angular thrust, thereby eliminating the hazards of dislocation. In addition, transplantation of the abductor muscles to a lower level makes the efficiency of this group approach the normal. Voluntary muscle control of the extremity can be initiated immediately after the operation, because no plaster fixation is required to ensure stability of the joint.

Shortening of the extremity was not great in this series, never exceeding three-quarters of an inch.

A CRITIQUE OF FAT EMBOLISM

BY ROBERT O. WHITSON, M.D., BAYTOWN, TEXAS

For some reason, certain patients with fractures suddenly become worse, one to several days after entering the hospital. On admission, the pulse and blood pressure are nearly normal, or quickly return to near normal limits after the administration of crystalloid solutions, plasma, or blood. Sometimes the turn for the worse follows anaesthesia for an indicated manipulation or an open reduction. During or following the procedure, the patient goes into severe shock and attempts at resuscitation are of no avail. At other times, the patient is in the ward and apparently doing well except for mild to moderate dyspnoea. Then signs of pulmonary oedema and mental confusion develop; if these continue and progress, the patient goes into shock and expires. Then, if an autopsy is obtained, the pathologist is usually requested to look for fat emboli. Since enough evidence to make an anatomical diagnosis of fat embolism is almost invariably present, the fatalistic conclusion that nothing effective could have been done is drawn.

However, a close analysis of the concept of fat embolism reveals that such a post-mortem diagnosis is unproved and illogical. It is possible now to correlate the clinical signs and symptoms of so-called fat embolism with our present-day knowledge of traumatic shock. Fat embolism due to fracture is hardly a satisfactory diagnosis for the primary cause of death.

Incidence

A diagnosis of fat embolism as the cause of death has been made in a wide variety of diseases. Scuderi presented an excellent review of the literature up to 1934 [8], and much of the material for this paper was taken from his review. The condition most commonly reported as initiating fat embolism is a fracture of the long bones, usually multiple and severe; injuries to fatty tissues other than the bone marrow have also been credited with causing fat embolism. Among these injuries are burns, contusions (including difficult labor), and even surgical incisions of the adipose tissues in obese patients. Fat embolism has even been found following numerous non-traumatic diseases,—such as pneumonia resulting from influenza, acidosis, hepatitis, nephritis, chronic tuberculosis, and poisoning by numerous agents. Lehman and McNattin reported fat embolism in about half the lungs of fifty unselected autopsy specimens, most of which were from non-traumatic deaths. The existence of the anatomical findings of fat embolism following death from such a wide variety of diseases casts doubt on its importance as a cause of death. These findings of fat embolism are probably coincidental with the abnormal state which precedes death from most causes,—namely anoxyaemia. As will be shown, the microscopic findings described as "fat embolism" are really the result of an anoxyaemic death.

The failure of fat embolism to occur in certain surgical procedures is of significance; for, if the theory that bone-marrow fat enters the severed veins of fractured bones and produces symptoms of embolism is sound, the occurrence would be frequent in reconstructive bone surgery and intramedullary nailing. Likewise, in bone-grafting procedures, the donor area, particularly if the tibia is used, would present an ideal combination of factors for fat embolism to occur. While it is true that fat embolism has been reported following orthopaedic procedures, in most of these cases, the patient was either a poor risk (hip operations in the elderly) or the procedure was shocking (*brisement forcé*). In healthy individuals with adequate preoperative and postoperative care, fatal fat embolism does not occur following reconstructive surgery of the skeleton. Warren collected one hundred consecutive cases from the Army Institute of Pathology. Ninety-one followed serious fractures; four, blast injuries without fracture; three, burns; one, pressure asphyxia

without fracture; and one, soft-tissue trauma from shell fragments. The number of massive bone grafts, with the tibia used for donor bone, which have been performed by Army surgeons must be tremendous. If the above mentioned theory of fat embolism were sound, fatalities would have been reported from this group. There have been none reported. Similarly, intramedullary fixation of fractures has not been complicated by the theoretically predictable occurrence of fat embolism.

Pathology and Pathogenesis

According to the theory of fat embolism, fat enters the venous system at the site of injury. When adipose tissue or bone marrow has been traumatized, minute fat particles are liberated into the hematoma. These fat particles are washed into the ends of the veins opened by the trauma and, then, are carried to the lungs and brain, where they may produce embolism.

It is true that particles of fat can be demonstrated at sites of injury; but that blood and fat, extravasated into a hematoma, re-enter the venous circulation is contrary to the evidence. A study of the healing of closed fractures [11] and other contused wounds fails to reveal fat embolism taking place. Extravasation of blood into the site of the injury takes place from both arteries and veins. When the tension in the tissues equals the venous pressure, the veins collapse and thrombose. Later arterial bleeding is similarly stopped, and the vessels in bone channels are surrounded by a small amount of areolar tissue. Contrary to the speculations of Gauss, they are not held open by their bony wall. The collapse of these vessels is admittedly slower than that of vessels in other tissues, but thrombosis takes place shortly after the occurrence of fracture. Since there is no microscopic or other evidence that extravasated blood at sites of injury re-enters the venous circulation to any significant degree, it is illogical to hypothesize fat globules entering the circulation by this method. Crystalloid solutions, including various dyes, will enter the circulation by dialysis from almost any site. Except in children, in whom bone-marrow transfusion is feasible, corpuscular and colloid suspensions must be introduced directly into a sound vein. Staining of the lungs by dyes injected into a fracture hematoma is not proof that fat globules behave similarly.

Lehman and Moore reviewed the subject of fat embolism and added original investigations of their own. They noted that the one common factor in the varied conditions reported as causing fat embolism is a marked alteration in the chemical and physical characteristics of the blood. They reproduced experimentally the picture of fat embolism by the intravenous injection of ether and by pushing ether inhalation to death. Another experiment with intravenously injected fat led them to conclude that, if man has the same susceptibility to circulating fat as have dogs, there is insufficient fat in the marrow of a femur to cause death. Their final conclusion was that fat embolism results when the fat normally present in the blood becomes aggregated into larger particles because of changes in the blood, the medium, in which it is suspended. There is no convincing evidence, however, that the amount of fat in the blood or its composition is significantly altered following fractures[9]. That a reduction in the oxygen-carrying capacity of the blood may be the primary factor in the production of "fat embolism", while the fat content itself is coincidental, is suggested by their experimental results.

For a diagnosis of fat embolism to be made, the lungs must be found to be the seat of major changes, including pulmonary oedema, petechial and perivascular hemorrhages. On the hematoxylin and eosin preparations, large non-staining vacuoles, mostly intracellular, are seen [12]. On the fat-stain preparations, large conglomerations of fat are seen, which will generally be without structure and many times larger than the diameter of the cells or capillaries. Lehman and Moore discuss the difficulties of preparing fat-stained sections and suggest that frequently the accumulations of fat do not represent emboli but, instead, intracellular fat displaced by the microtome. That globules of fat can be

pushed through the capillaries of the lung to be carried to the central nervous system and there cause serious damage does not seem plausible. If some fat globules are small enough to go through the lung without damage, why do they cause obstruction elsewhere? If they are large enough to occlude the lung capillaries, then hemorrhage and oedema follow; blood flow in the involved vessel stops; and the embolus is trapped. Experimental embolism with minute particles demonstrates that the lungs have a remarkable vascular reserve [2]. There is no experimental evidence that emboli can traverse one capillary bed and cause damage in another.

Significant findings are present also in the central nervous system. Any part may be involved, but the damage is predominantly to the white matter of the cerebrum and brain stem. Congestion, perivascular oedema, and petechial hemorrhages are the characteristic findings. By proper techniques the presence of fat can also be demonstrated.

The kidneys, heart, liver, spleen, and mucosal surfaces are similarly involved.

Shock

The autopsy findings described for shock [13] are identical to those attributed to "fat embolism" except for the emphasis on accumulations of fat. If fat stains were done routinely, positive results should be frequently obtained, for: "Fatty degeneration is the accumulation of stainable fat in cells or organs where normally none is visible. It is a common type of degeneration and indicates a more severe injury than does cloudy swelling. In general, the cause may be said to be anoxemia, whether due to local interference with blood supply, severe generalized anemia, or toxins of bacterial or chemical origin." [1] Therefore, the presence of fat globules is a finding compatible with an anoxyaemic death, such as shock, and need not imply embolism. The one factor common to the many diverse conditions reported as resulting in fat embolism is anoxyaemia. Anoxyaemia, then, would appear to be the cause of the morbid state which has been labeled "fat embolism". In other words, intravascular fat is the result rather than the cause of capillary stagnation.

Progress is continually being made in our understanding of shock. The development and refinement of laboratory techniques have contributed much, particularly the determination of blood volume. Every surgeon is familiar with the clinical manifestations of shock of which the basic cause is a discrepancy between the circulating blood volume and the circulatory bed. This is followed by numerous sustaining and contributory changes in the blood chemistry and physiology. However, frequently missed is the condition of impending shock. Here, there is a serious reduction in the blood volume, but the neurovascular reflexes have come into play and largely corrected the circulatory clinical manifestations. If the patient's reserve is good, he may, without vigorous treatment, return to normal. On the other hand, the gradual development of associated aberrations or further traumatic insults may precipitate a severe shock state which is often irreversible.

Patients with severe fractures suffer either from shock or impending shock. Phemister and Laester have demonstrated that a large part of the blood volume may be lost into the tissues at the site of a closed fracture. The blood loss from open fractures is obvious and compelling; however, the patient may show only a diminution of the pulse pressure with a slight increase in the pulse and respiratory rates. If the blood pressure is initially low, a transfusion may return it to nearly normal; but, unless the blood and plasma replacement is complete, the patient is still in poor condition. The volume required for complete replacement is much greater than is generally appreciated. It has been said that death from shock occurs in three hours, from fat embolism in three days [10]. The cumulative effects of abnormal blood volume, abnormal blood chemistry, and of severe anaemia may progress to a fatal outcome over a period of three days or more.

Symptoms and Treatment

The symptoms attributed to fat embolism are identical to those of anoxyaemia or

shock. Dyspnoea and signs of congestion in the chest appear as the pulmonary oedema develops. There is an increase in the pulse rate and, finally, a fall in the systolic pressure. Terminally, there is severe circulatory collapse. Petechial hemorrhages may occur in the skin and elsewhere, indicating increased capillary fragility. Coma or delirium and sometimes an elevation of the temperature to as high as 107 degrees indicate that damage to the central nervous system has occurred. The diagnosis of fat embolism cannot be made with certainty prior to death, because all the symptoms and findings may be indicative of other conditions. The presence of fat in the sputum and urine has been considered important by some authors; others have shown that various other disease states may also produce this phenomenon. There is no pathognomonic laboratory finding for fat embolism [9].

Regimens of therapy directed toward removing the fat globules from the blood stream have been uniformly unsuccessful. A plan of treatment has been evolved, utilizing measures which should be instigated for the prevention or alleviation of shock. Adequate splintage and early reduction of fractures are recommended, with the use of a tourniquet when feasible; repeated manipulations are to be avoided. Good nursing care and general supportive measures are beneficial.

The successful treatment of "fat embolism" in a severely injured patient has been recorded [3]. Oxygen with vigorous intravenous blood and plasma therapy was used. It may be noted that the initial hematocrit was 37.8. This finding and the outcome suggest that actually hemorrhagic anaemia was the basic disorder. Prevention of shock by complete restoration of blood volume and chemistry is sound prophylaxis for "fat embolism".

CONCLUSIONS

If one takes a critical attitude and demands proof, a survey of the literature fails to show convincing evidence in favor of the theory of fat embolism. On the other hand, it appears evident that the diagnosis of fat embolism as a cause of death should be discontinued in favor of anoxyaemia. The etiology of the anoxyaemia may be the aberrations of body fluids following severe trauma, or it may be a non-traumatic disorder of body chemistry.

The persistence of the concept of fat embolism has been a hindrance to the understanding and treatment of certain post-traumatic complications. The etiology and prevention of these disorders are not yet understood.

REFERENCES

1. Anderson, W. A. D.: Synopsis of Pathology, Ed. 1, p. 36. St. Louis, C. V. Mosby Co., 1942.
2. Dunn, J. S.: The Effects of Multiple Embolism of Pulmonary Arterioles. Quarterly J. Med., **13:** 129–147, 1920.
3. Dunphy, J. E., and Ilfeld, F. W.: Fat Embolism. Am. J. Surg., **77:** 737–743, 1949.
4. Gauss, Harry: The Pathology of Fat Embolism. Arch. Surg., **9:** 593–605, 1924.
5. Lehman, E. P., and McNattin, R. F.: Fat Embolism: II. Incidence at Postmortem. Arch. Surg., **17:** 179–189, 1928.
6. Lehman, E. P., and Moore, R. M.: Fat Embolism, Including Experimental Production without Trauma. Arch. Surg., **14:** 621–662, 1927.
7. Phemister, D. B., and Laester, C. H.: Local Fluid Loss, Nerve Stimuli and Toxins in the Causation of Shock. Ann. Surg., **121:** 803–820, 1945.
8. Scuderi, C. S.: The Present Status of Fat Embolism. A Bibliographic Review. International Surg. Digest, **18:** 195–215, 1934.
9. Scuderi, C. S.: Fat Embolism. A Clinical and Experimental Study. Surg., Gynec., and Obstet., **72:** 732–746, 1941.
10. Speed, Kellogg: A Text-Book of Fractures and Dislocations Covering Their Pathology, Diagnosis, and Treatment. Philadelphia, Lea and Febiger, 1916.
11. Urist, M. R., and Johnson, R. W.: Calcification and Ossification. IV. The Healing of Fractures in Man Under Clinical Conditions. J. Bone and Joint Surg., **25:** 375–426, Apr. 1943.
12. Warren, S.: Fat Embolism. Am. J. Pathol., **22:** 69–87, 1946.
13. White, C. S., and Weinstein, J. J.: Blood Derivatives and Substitutes; Shock. Baltimore, Williams and Wilkins Co., 1947.

XANTHOMATOUS JOINT TUMORS *

BY W. L. MINEAR, M.D., HOT SPRINGS, NEW MEXICO

From the Campbell Clinic, Memphis, Tennessee

INTRODUCTION

Since Gustav Simon, in 1865, reported the first case of xanthoma in the knee joint, there have been scattered references in the literature to similar tumors. The synonyms are numerous, as recently pointed out by Jaffe, Lichtenstein, and Sutro, who preferred the term, "pigmented villonodular synovitis". Dowd, in 1912, used the term, "villous arthritis of the knee". Blanco, in 1921, referred to a case of giant-cell tumor in the knee joint. Kling and Sashin, in 1935, referred to "hemorrhagic villous synovitis of the knee". Other designations commonly used are xanthogranuloma and giant-cell tumor. These terms are mentioned because they indicate some of the important clinical and pathological features of intra-articular xanthoma.

In a review of xanthomatous tumors of synovial membrane, DeSanto and Wilson, in 1939, based their discussion upon an analysis of forty-one cases, nine of which they had collected. Galloway, Broders, and Ghormley reported five new cases in 1940. Smith-Petersen, in 1944, reported an unusual case in the hip joint[3]. Jaffe, Lichtenstein, and Sutro, in 1941, reported twenty joint xanthomata.

Described herein are five joint xanthomata which the author found from the pathological collection of the Campbell Clinic. This makes a total of approximately eighty-one joint xanthomata described in the literature.

CASE REPORTS

CASE 1. A man, aged fifty-three, with a diffuse, boggy swelling of the right knee joint, was first seen in July 1932. The patient stated that he had been kicked on the right knee by a mule in 1901, and had been unable to walk for one month. In 1906 he had the measles, and soon afterward noticed that his right knee was swollen. The knee had gradually increased in size, and in the few months preceding examination the pain had been severe.

The circumference of the right knee was nineteen inches; that of the left knee was fifteen inches. The soft tissues were boggy, and there was an increase of local heat. The range of motion was from 70 to 100 degrees, with pain on forced motion beyond these limits. The patient had a slight limp, but walked without support.

Roentgenograms showed fusiform periarticular swelling with no evidence of oedema. The osseous architecture was characterized by slight coarsening of the trabeculations, thinning of the osseous articular cortices, asymmetrical reduction in the interosseous spacing, and conspicuous expansion of the capsule with prominence of both the supracondylar and retrocondylar pouches (Fig. 1). These findings are consistent with disuse atrophy of muscles and bones, beginning destruction of articular cartilages, and intra-articular tumor. The preoperative diagnosis was benign tumor of the knee joint.

On July 8, 1932, a total synovectomy and arthrotomy were done.

The pathologist reported that, grossly, the joint cavity was distended by a chocolate-colored mass which occupied the suprapatellar pouch and the anterior and posterior compartments of the knee joint. The specimen consisted of two double handfuls of soft tissue with many small and large nodular masses on a base of fibrous connective tissue. It had the consistency of rubber, and many hard and soft nodules were present on the surface. The cut surface resembled fine sponge rubber and was a mixture of gray and pale yellow in color. Microscopically, the sections were composed of fibrous connective tissue containing many cells, the nuclei of which varied greatly in size and shape. Some were oval, some spindle-shaped, and others polyhedral. There was much gold and yellow pigment scattered throughout the section, most of it being held by large oval to polyhedral cells, resembling large monocytes and histiocytes. There were areas of foam cells and occasional epulis-type giant cells. The diagnosis was xanthoma.

* Submitted as part of a thesis in partial fulfillment of the requirements for the degree of Master of Science in Orthopaedic Surgery at the University of Tennessee, Memphis.

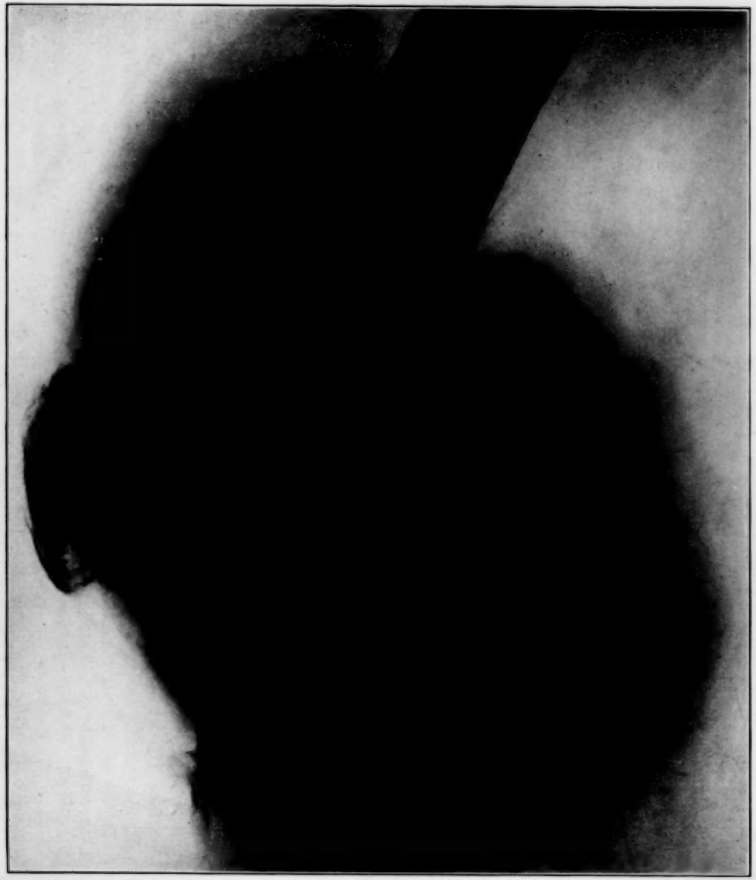


FIG. 1

FIG. 2-A

Fig. 1: Case 1. Lateral view of knee, showing xanthoma filling the anterior and posterior compartments and the suprapatellar pouch. Osseous architecture characterized by slight coarsening of the trabeculations, consistent with disuse atrophy.

Fig. 2-A: Case 2. Lateral roentgenogram showing soft-tissue tumefaction regional to lateral malleolus and posterolateral aspect of the ankle. This tumor is sharply marginated and lobulated. The osseous architecture is normal; articular cortices normal. Slight widening of capsular outline is visible anterior to joint. Findings consistent with a soft-tissue tumor.

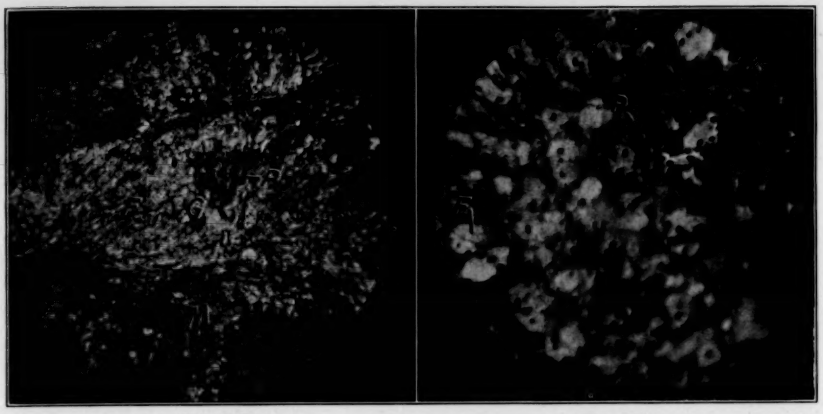


FIG. 2-B FIG. 2-C

F = foam cells. *P* = pigment. *G* = giant cells. *M* = mother cells.

CASE 2. A woman, aged thirty, with a painful tumor of the left ankle, was first seen in July 1932. Seven years earlier the patient had sprained her left ankle. About two weeks after the injury she noticed a small tumor, just anterior to the lateral malleolus. The tumor had gradually enlarged and had extended posteriorly to the ankle joint and around to the medial malleolus. There was no pain on weight-bearing, but the patient experienced some discomfort at night.

Examination showed a soft-tissue tumor, 4 by 5 by 5 centimeters, anterior to the lateral malleolus with extension around the posterior aspect of the ankle joint, beneath the tendo achillis, to the medial malleolus. The tumor mass was soft and freely movable. It did not seem to be attached to bone.

The patient refused surgery, but returned for examination five years later, complaining of pain and increase in size of the tumor. At that time the tumor presented anterior to the lateral malleolus and measured 4 by 5 by 6 centimeters. It seemed to be attached to the deeper structures. There was some increase in local heat.

Roentgenographic examination showed soft-tissue tumefaction regional to the lateral condyle and posterolateral aspect of the ankle (Fig. 2-A). This was rather sharply marginated in outline within the posterior triangle (no evidence of oedema). The osseous architecture and the articular cortices were normal. There was slight widening of the interosseous spacing and slight expansion of the capsular outlines in the anterior aspect of the joint. The findings were consistent with soft-tissue tumor, apparently external to the joint confines, although the capsule was definitely expanded.

The preoperative diagnosis was soft-tissue tumor. At operation the tumor was completely removed. Soft tissue was found in the tarsal joints, extending around the tendo achillis, peroneal tendons, and the structures on the medial side of the ankle.

The blood cholesterol was 145 milligrams per 100 cubic centimeters.

The pathologist reported that the specimen consisted of an irregular, lobulated, encapsulated tumor, measuring 5 by 7 by 9 centimeters. On cut section, the tumor was divided into compartments by thick fibrous bands, and was of a mottled chocolate-brown color. Microscopically the section was composed of fibrous-tissue trabeculae, between which were the various cells typical of a xanthoma,—stroma cells, foam cells, pigment cells, and occasional epulis giant cells (Figs. 2-B and 2-C). There was also extracellular pigment. The diagnosis was xanthoma.

CASE 3. A woman, aged forty-seven, with a painful tumor of the right ankle, was first seen in April 1934. Three months prior to admission, the patient had sprained her right ankle and had experienced severe pain and considerable swelling for several days. She continued walking and sprained her ankle four additional times in the following three weeks. After that she walked with a limp, and the pain and swelling of the right ankle joint persisted.

On examination the right ankle was considerably swollen. There was bilateral pes planus, third degree, and bilateral hallux valgus. There was acute tenderness on pressure over the medial malleolus. Dorsiflexion and inversion were limited by 50 per cent.; eversion was limited 25 per cent.

Roentgenographic examination disclosed a prominence of the soft tissue anterior to the ankle joint with a pulsation type of erosion of the anterior aspect and distal extremity of the tibia and the anterior aspect of the talus (Fig. 3). There was regional soft-tissue tumefaction, but no evidence of oedema. The articular

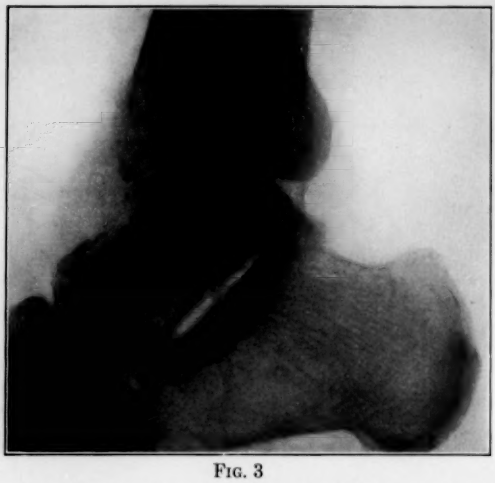


FIG. 3

Case 3. Lateral view of ankle joint. A soft-tissue tumor is visible with erosion of the talus and tibia. Articular cortices are negative; intraosseous spacing normal. Findings consistent with an intra-articular tumor, vascular in character. Amputation was required because of extensive damage.

cortices were negative. The interosseous spacing was normal. There was an expansion of the capsular outlines anteriorly and posteriorly. The findings were consistent with intra-articular tumor, vascular in character. The preoperative diagnosis was benign tumor of the ankle.

The right leg was amputated through the upper third of the tibia. (Extensive invasion of the tumor throughout the proximal portion of the tarsus made amputation the procedure of choice.)

The pathologist's report was as follows: The specimen consisted of the right foot and the lower two-thirds of the tibia and fibula. There was a surgical wound on the anterolateral aspect of the ankle joint, showing in its base a part of the articular surface of the tibia and talus. There was an area of bony destruction of the body of the talus and the anterior adjacent portion of the tibia. The medial malleolus was practically replaced by tumor. The tumor was soft, lobulated, and grayish-yellow to brown in color. Tumor tissue was found between the tibia and fibula throughout the ankle and subtalar joints. Small deposits of the tumor were found on the interosseous membrane above the joint. The saline solution in which the tissue was immersed presented a yellowish color. Microscopically, the section presented a very cellular structure, split by fibrous-tissue trabeculae. There were areas of foam cells, many epulis giant cells, and many phagocytes containing golden-yellow pigment. This pigment was extracellular as well as intracellular. The diagnosis was xanthoma.

CASE 4. A white woman, aged thirty-six, was first seen by Willis C. Campbell, M.D., in April 1924. The patient stated that, while leaning over a bed, she felt a sudden pain and locking of the right knee joint. At examination, a mass, one inch in diameter, apparently fluctuating and attached to the external cartilage, was palpated. Operation was advised. Roentgenograms of the knee were negative.

The preoperative diagnosis was tumor of the knee, type not stated.

At operation through a lateral parapatellar incision, the right knee joint was explored. The synovial membrane was congested. The articular surface and cartilage of the joint were normal. A pedunculated tumor was seen arising from the synovial membrane lateral to the patella. This appeared to be a xanthoma. The tumor was removed and, after the usual closure, a posterior plaster splint was applied to the knee.

The pathologist reported a pedunculated tumor, one by one and one-half inches, attached to the synovial membrane of the right knee joint, lateral to the patella. The synovial fluid was increased slightly and was blood-stained. The synovial membrane (lateral surface of joint) was injected. Otherwise, the articular cartilage and the menisci were normal. No loose bodies were found. The tumor was solid, encapsulated and, on section, a yellowish-cream color, firm in consistency, but with no fibrous or cartilage tissue. A hemorrhagic area was present at the tip of the pedunculated tumor. Microscopically, the tissue was made up of foam cells in scattered groups with occasional giant cells and scant intracelluar and extracellular pigment, all embedded in a loose fibrous connective tissue. The diagnosis was pedunculated synovial xanthoma.

CASE 5. (From records of C. C. McReynolds, M.D., May 22, 1945, summarized by Malcolm Downs, M.D.) The patient was a white male of fifty-six years, who was a repair man and had been doing heavy work for several years. He was first seen at the White Memorial Hospital on January 31, 1942, complaining of recurring attacks of pain and massive effusion of the right knee since trauma to the knee six years previously. Each exacerbation of the acute symptoms followed a period of excessive use of the knee.

Examination disclosed that a mass resembling a Baker's cyst, measuring approximately 8 by 8 by 12 centimeters, was palpable in the popliteal area. This mass had first been noticed three or four years previously and had gradually become enlarged. The patient stated that this area always became tender and larger during an acute flare-up. The past history was essentially negative. There was no history of diathesis.

Physical examination revealed a well developed male of 210 pounds with no physical abnormalities except those of the right knee. The hemoglobin was 98 per cent., red-blood-cell count 5,100,000, and white-blood-cell count 8,500. The distribution of lymphocytes, monocytes, and polymorphonuclear cells was normal.

Roentgenographic examination on February 1, 1942 (Fig. 4) was as follows: "In the main the bony structures of the knee appear to be intact. There is localized atrophy of the anterior portion of one of the condyles of the femur, but without break in the cortex. No evidence of change in the infrapatellar fat pad. No evidence of periarticular involvement. The joint space is not materially narrowed. Findings essentially negative except for localized atrophy of the anterior aspect of one of the femoral condyles, the origin of which is not apparent."

Operation was performed on February 15, 1942, by C. C. McReynolds, M.D., at which time the following report was made: "A six-inch incision was made in the right popliteal fossa. The fascia lata was opened, exposing a tumor of fair size, cystic in nature, between the semimembranosus and medial head of the gastrocnemius. This tumor was dissected by blunt and sharp dissection, and found to attach fairly close to the gastrocnemius and the semimembranosus. It also entered into the knee joint posteriorly. Between the heads of the gastrocnemius was found a smaller cyst approximately two inches in diameter, containing yellow fluid. This was covered by the plantaris muscle which was dissected away. This tumor also entered the joint at a separate opening. There were very few adhesions around these cysts. On exposure of the knee joint posteriorly, several papillary projections were removed for pathological study, but all of them could not be excised. The short saphenous vein was ligated. The wound was saturated with four grams of sulfanilamide and the fascia lata closed with continuous 00 catgut. There was very little bleeding. No tourniquet was used. Continuous dermal suture was used in the skin. The patient left surgery in good condition."

The postoperative diagnosis was Baker's cyst with papillomata of undetermined nature.

The pathologist's examination was as follows: Specimen *A* consisted of a cystlike structure, measuring 4 by 5 by 6 centimeters. The external surface bore a number of fibrofatty tags and the lining was smooth, but quite markedly trabeculated. Part of the lining bore some friable light gray material which stripped off with difficulty. Specimen *B* was also a cystic fragment, 1 by 2.5 by 3 centimeters in size. The lumen was only about 1 centimeter in diameter and the lining was smooth and glistening. There was a similar but larger cyst, measuring 5 by 7 by 11 centimeters, and the wall was rather rough and trabeculated. The wall of each cyst was tough and contained some brick-red areas mingled with dark brown. The external surface was quite well circumscribed. Specimen *C* consisted of several irregular polypoid structures (removed from inside the knee joint and attached by pedicles to the synovial lining of the joint proper), two of which were moderately congested. The largest measured 1.3 by 2 by 7 centimeters; the external and cut surfaces contained large amounts of brick-red and brown as well as yellow pigment, similar to that seen in specimen *B*. These polyps together formed a mass 12 millimeters in diameter.

Microscopically, *A* consisted of dense fibrous stroma containing some areas of hemorrhage, numerous distended thin-walled vessels, and moderate round-cell reaction. It appeared to be a cyst wall with pink-stained granular material. This material contained a few round cells and showed some evidence of fibrous organization.

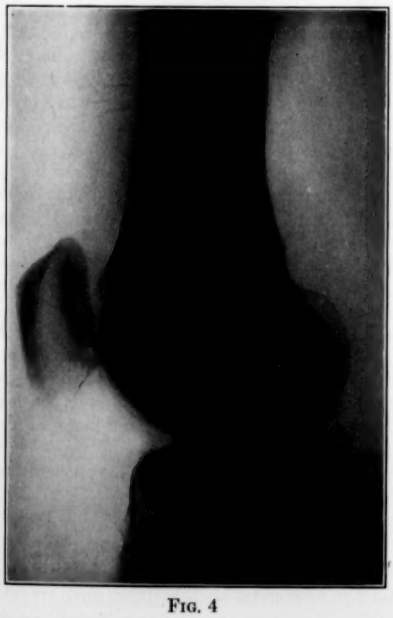


FIG. 4

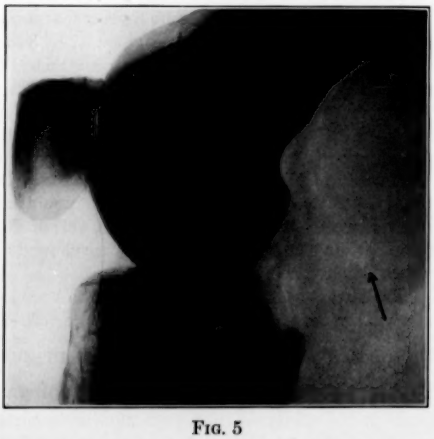


FIG. 5

Fig. 4: Case 5. February 1, 1942. Lateral view shows some bone atrophy of the anterior femoral condyle. The suprapatellar pouch is definitely expanded, probably with fluid. There is no definite evidence of tumor.

Fig. 5: Lateral roentgenogram of knee with an extra-articular xanthoma. There is normal bony architecture. There is only the suggestion of a soft-tissue mass in the popliteal fossa.

Sections labeled *B* also showed some dense fibrous stroma, containing hemorrhage and considerable round-cell reaction. A number of striated muscle bundles were attached. The cyst lining here showed two or three layers of endothelial cells. In the underlying tissue were numerous brown pigmented phagocytes and a number of irregular sheets of closely packed dark cells. The nuclei were round or oval and showed little accompanying cytoplasm. There was some diffuse lymphoid infiltration, including perivascular reaction and a few dense foci. Sections labeled *C* were similar in appearance, but the cells were separated by hyaline material or oedema. Some fields showed numerous foamy xanthomatous cells; others contained giant cells with many nuclei. Some fields also contained yellow-brown pigment accumulations. The tissues were fairly typical of xanthic giant-cell tumor of tendon sheath and a similar condition of synovial membrane called villonodular synovitis. There seemed to be no evidence of malignant growth. The diagnosis was xanthic giant-cell tumor of the knee and villous synovitis of the knee joint.

The patient had an uneventful postoperative course and was discharged on February 25. He was last admitted to this Hospital on June 3, 1942, at which time a complete synovectomy of the right knee was done.

The roentgenographic examination of June 3, 1942, showed a localized area of atrophy about the anterior portion of the femoral condyle, which seemed to have increased somewhat in size. The bony structures otherwise were intact. No evidence of periarticular change was demonstrated.

At operation a ten-inch medial parapatellar incison was made, centered opposite the patella. The synovial lining of the knee joint was greatly thickened and oedematous. Its internal surface was covered with tabs of dark brownish tissue, embedded in fibrous exudate. This tissue extended into the intercondylar notch, investing the bony surface and the cruciate ligaments. It was also present in small deposits along the menisci. The articular cartilage surfaces showed a moderate degree of chondromalacia, but without fissuring or bony denudation. There was a thin pannus growing onto the joint surface, both of the femur and of the tibia. The entire synovial lining of the anterior compartment of the knee joint was excised by blunt dissection. The menisci and both cruciate ligaments were removed. The posterior compartment of the knee joint still contained a few tabs of the xanthoma, and most of these were excised. Six grams of sulfanilamide was placed in the wound. The incision was closed in layers, with the use of chromic 0 continuous suture, subcutaneous closure with chromic 00. The tourniquet time was two hours and three minutes.

The postoperative diagnosis was xanthoma of the right knee joint.

The pathological specimen consisted of about 2 cubic centimeters of coagulated light yellow fluid which contained thick yellow mucus. There was also a large irregular fragment of thick membrane which was said to be the synovial lining of the knee joint. The outer aspect bore a moderate amount of fat and the inner surface bore numerous, slightly congested polyps which varied markedly in size. This fragment measured 1.7 by 11 by 20 centimeters in greatest size. The polyps had smooth surfaces, but they varied considerably in color, some being light gray and others medium gray-brown. At some points there was considerable oedematous fibrinous exudate, quite closely adherent to the inner surface of the membrane. The polypoid masses varied from 3 centimeters in diameter to one which was 0.6 by 1.3 by 2.5 centimeters. There was a diverticulum with an opening 7 millimeters in diameter, and this space measured 2 by 3 by 3 centimeters. This diverticulum was filled with light yellow-gray fibrinous exudate from which some clear yellow fluid could be expressed. There was a separate polyp with a smooth, light yellow-gray external surface, measuring 0.5 by 1.5 by 2.2 centimeters. There were three or four similar but smaller fragments of synovial lining, the largest of which contained a flattened polyp 0.8 by 1.7 by 3 centimeters. A small amount of muscle was found on the large one, already described, but none was attached to these smaller pieces. The tendon consisted of one fragment, 0.9 by 1.2 by 3.5 centimeters. The cartilage consisted of three pieces from the menisci, the largest consisting of a wedge-shaped piece, 0.8 by 3 by 3.5 centimeters.

Microscopic Findings: Section through the polyp showed some loose vascular fibrous stroma at one end, which was covered by a layer of leukocytes and endothelial cells. Other portions showed round-cell infiltration, numerous brown pigmented phagocytes, and many large, pale xanthomatous cells. Other fragments consisted of dense fibrous tissue or areas like that noted in the polyp. Some portions showed areas of widespread necrosis; several fields contained giant cells. One of the fragments showed striated muscle fibers on the deep surface. Section through synovial membrane showed a large amount of granular, albuminous material, also numerous leukocytes and round cells.

The diagnosis was villous synovitis of the knee joint, and xanthic giant-cell tumor of the cruciate ligaments and menisci. This tumor was obviously a diffuse xanthoma of the synovial membrane.

DISCUSSION

A review of the clinical features of xanthomatous tumors of synovial membrane, based on an analysis of forty-one cases presented by DeSanto and Wilson and twenty cases by Jaffe, Lichtenstein, and Sutro, illustrates how the five tumors just described fit in with a larger group of tumors.

Fifty-nine per cent. of the tumors in DeSanto and Wilson's cases were in males. The majority occurred in patients between twenty and forty years, although two were reported

in the age group between fifty-one and sixty. Solitary, multiple, and diffuse types have been described. The location was predominantly in the knee joint; a few were in the ankle and one in the tarsus. A history of trauma was obtained in twenty-three cases. The duration of symptoms was from one day to twenty years. Pain, varying from mild to severe, was present in thirty-four cases, absent in two, and not mentioned in five. Mechanical interference was mentioned in seven of the histories with various types of catching and restriction of extension. These symptoms are more characteristic in the solitary or multiple nodular types than in the diffuse type. A palpable tumor was reported in twenty-nine of the forty-one cases; swelling was mentioned in thirty-one cases. Aspiration was performed in seven cases. Roentgenographic examination was reported as negative in many cases, but in those of long standing there was moderate decalcification of bone and erosion from tumor pressure. DeSanto and Wilson based the diagnosis upon an "obscure fluid swelling of the knee joint in association with intermittent pain and with mild symptoms of mechanical interference with function". The presence of a tumor and the aspiration of thick orange-brown fluid are very significant; the presence of cholesterol in large amounts is pathognomonic. Treatment consisted in excision of the tumor. Recurrence took place in seven of the forty-one cases, the earliest recurrence in four months and the latest in eight years. "No instance of a benign giant-cell xanthoma undergoing malignant transformation has ever been reported."

Jaffe and his associates suggested postoperative roentgenotherapy as a favorable method of reducing recurrences. In the twenty cases reported by them, the diffuse form of the tumor occurred in the second and third decades, whereas the circumscribed form occurred in the third, fourth, and fifth decades. Again, the lesion was more common in males. With the diffuse form, the patients consulted a physician after symptoms had been present from two to three years; with the circumscribed type, after an average of four and one-half years. Symptoms were pain and swelling, often intermittent in nature. Less common complaints were stiffness, locking, snapping on extension, and limp. Trauma was not considered to be an important associated finding. Roentgenographic diagnosis was thought to be of little value. Lewis and Aitken both pointed out that a calcified tumor of a joint is probably a synovioma, a rare and often malignant sarcoma, and that calcification did not occur in xanthoma. The blood-cholesterol values were found in the upper range of normal in four cases. Jaffe, Lichtenstein, and Sutro agreed that the most important single diagnostic aid was the aspiration of serosanguineous fluid on repeated occasions. Of course, recent injury and hemophilia must be ruled out.

Case 30131 of the Massachusetts General Hospital had roentgenographic characteristics of tuberculosis and hypertrophic arthritis of the hip. Pressure erosion is not uncommon with xanthoma, but sclerosis has not been reported. However, the microscopic picture of this case was xanthoma or pigmented villonodular synovitis. The question was asked whether changes of this type could not occur in a chronic synovitis of hypertrophic arthritis. Jaffe and his associates found that such a change did not occur.

The origin of the various cellular constituents of xanthoma has been a subject of long controversy. At present, the xanthoma cell is thought to be a phagocytic cell that has devoured cholesterol and cholesterol ester substances which have been removed from the surrounding tissue juices. Alteration of lipoid metabolism or local changes in the ratio of these substances supplies an excess of the lipoid material.

The giant cell is of the foreign-body type and is present in proportion to the debris present in the tissue. Galloway, Broders, and Ghormley cited Mallory and Broders as stating that this giant cell is essentially an osteoclast. In Case 2, with extensive bone destruction, an excessive number of these cells were present.

The orange-yellow color is due to carotene or xanthophyll pigments normally present in blood serum and having an affinity for cholesterol esters, which are colorless.

The stroma cell is thought to be an endothelial cell, as is the lining of synovial mem-

brane, bursae, and tendon sheaths. Injury and hemorrhage in this tissue produce the xanthoma.

ETIOLOGY AND PATHOGENESIS

Jaffe, Lichtenstein, and Sutro favored the theory that the xanthoma represents an inflammatory response, the agent being unknown. They did not believe that the inciting agent was a bacterial one, or due to lipoid imbalance or local repeated hemorrhage. They rejected the theory of Geschickter and Copeland, who maintained that the xanthomata, particularly those appearing in tendon sheaths, develop through proliferation of the osteoclasts in associated sesamoid bones. Jaffe and his co-workers felt that hyperplasia of undifferentiated (especially perivascular) connective-tissue cells in the subsynovial and subbursal tissues, and the assumption of phagocytic qualities by these cells, suggests inflammation. This accounts for their use of the suffix "itis", and designation of the lesion as "pigmented villonodular synovitis, bursitis and tenosynovitis".

Due to the fact that the foam cells or xanthoma cells are derived from the macrophagic or reticulo-endothelial system and are modified to contain cholesterol, they are thought not to be true tumor cells in the oncological sense.

Jaffe, Lichtenstein, and Sutro found that hemorrhage into villae, as in a hemophilic joint, does not produce the xanthoma picture, nor do repeated injections of autogenous blood or ferric chloride into joints. Fat necrosis following trauma does not resemble xanthoma tissue. Injections of cholesterol or cholesterol ester, alone or combined with ferric chloride, did not produce xanthoma tissue. Therefore, its true nature is unknown.

SUMMARY

Joint xanthoma is suggested by the presence of a chronic mono-articular lesion (often a palpable tumor) of the knee or ankle. Aspiration produces sterile serosanguineous exudate, sometimes laden with cholesterol. The roentgenograms show a non-calcified soft-tumor mass in advanced cases, associated with pressure erosion of the bone.

NOTE: The author wishes to thank the Staff of the Campbell Clinic, Memphis, Tennessee, for their generous help in the preparation of this paper and for the use of the clinical records and laboratory material from which the case reports were compiled. Thanks are extended to C. C. McReynolds, M.D., for his kind permission to use the clinical and laboratory records of Case 1.

Colonel A. A. DeLorimier, formerly of the Army School of Roentgenology, read the roentgenograms in Cases 1, 2, and 3. Mr. C. F. Ingram, of the Campbell Clinic, prepared the illustrations.

REFERENCES

1. AITKEN, A. P.: Roentgenographic Recognition of Synovioma. J. Bone and Joint Surg., **23**: 950–952, Oct. 1941.
2. BLANCO, PIO: Giant-Cell Tumor in the Knee Joint: Report of a Case. J. Orthop. Surg., **3**: 156–157, Apr. 1921.
3. CASE RECORDS OF THE MASSACHUSETTS GENERAL HOSPITAL: Case 30131. New England J. Med., **230**: 409–412, 1944.
4. DESANTO, D. A., and WILSON, P. D.: Xanthomatous Tumors of Joints. J. Bone and Joint Surg., **21**: 531–558, July 1939.
5. DOWD, C. N.: Villous Arthritis of the Knee (Sarcoma). Ann. Surg., **56**: 363–365, 1912.
6. GALLOWAY, J. D. B.; BRODERS, A. C.; and GHORMLEY, R. K.: Xanthoma of Tendon Sheaths and Synovial Membranes. A Clinical and Pathological Study. Arch. Surg., **40**: 485–538, 1940.
7. GESCHICKTER, C. F., and COPELAND, M. M.: Tumors of Bone (Including the Jaws and Joints), pp. 747–753. New York, Published by Am. J. Cancer, 1936.
8. JAFFE, H. L.; LICHTENSTEIN, L.; and SUTRO, C. J.: Pigmented Villonodular Synovitis, Bursitis and Tenosynovitis. Discussion of Synovial and Bursal Equivalents of Tenosynovial Lesion Commonly Denoted as Xanthoma, Xanthogranuloma, Giant Cell Tumor or Myeloplaxoma of Tendon Sheath, with Some Consideration of This Tendon Sheath Lesion Itself. Arch. Pathol., **31**: 731–765, 1941.
9. KLING, D. H., and SASHIN, DAVID: Hemorrhagic Villous Synovitis of the Knee Joint Due to Xanthoma. Report of a Case. Arch. Surg., **30**: 52–61, 1935.
10. LEWIS, R. W.: Roentgen Recognition of Synovioma. Am. J. Roentgenol., **44**: 170–174, 1940.
11. SIMON, GUSTAV: Extirpation einer sehr grossen, mit dickem Stiele angewachsenen Kniegelenkmaus mit glücklichem Erfolge. Arch. f. Klin. Chir., **6**: 573–576, 1864–1865.

SYNOVIAL SARCOMATA *

BY JOHN F. TILLOTSON, M.D., ROCHESTER, MINNESOTA
Fellow in Orthopaedic Surgery, Mayo Foundation

JOHN R. MCDONALD, M.D., ROCHESTER, MINNESOTA
Division of Surgical Pathology, Mayo Clinic

AND JOSEPH M. JANES, M.D., ROCHESTER, MINNESOTA
Section on Orthopaedic Surgery, Mayo Clinic

Synovial sarcomata may be defined as malignant tumors of synovial origin. They arise from any one of the three synovial structures,—that is, joint capsules, bursae, and tendon sheaths.

The normal synovial membrane consists of an intima, varying from a membrane of many layers of round, oval, or even cubical cells to an incomplete lining of flattened inconspicuous cells, and a subintimal supporting layer of connective tissue. This layer may vary from one of exceedingly vascular, loose connective tissue to one of dense, fibrous connective tissue. The multilayered intima on loose supporting connective tissue may present crypts or villi. Its function may be characterized as a connective-tissue sleeve, thus allowing motion, in which secretory elements are interposed [18].

Malignant tumors may develop from either of the two layers which make up the synovial membrane. A tumor arising from the supporting layer of fibrous tissue may be indistinguishable from a true fibrosarcoma; a tumor arising from the intima presents a typical picture of synovial or adenomatous-like elements mixed with those of fibrosarcomatous appearance. The authors have not attempted to include the synovial fibrosarcomatous group in this series. Consequently all of these tumors show, at least in some places, the characteristic synovial elements.

The term used for these tumors, then, will be "synovial sarcomata", of which we recognize two separate types,—namely, the typical or adenomatous type and the fibrosarcomatous type. If an attempt is made to distinguish the fibrosarcoma of synovial origin, the tumor should be so labeled, and should be considered as a distinct type of synovial sarcoma identical with fibrosarcoma. It may be called properly a "synovial fibrosarcoma", thus reserving the term "synovial sarcoma" for the typical type.

Normal structural and functional peculiarities [2] of the synovial membrane are reproduced in malignant tumors with varying degrees of perfection. In some tumors the fibrous elements may be the most conspicuous; in others the villous or adenomatous pattern may dominate.

The term "synovioma", although in common usage since Smith's paper in 1927, has frequently included benign tumors of synovial origin, especially xanthomata. In view of this and because of the numerous other expressions which have been employed to designate the tumor, the authors feel that a term should be used which leaves no doubt as to the malignant nature of the tumor; "synovial sarcoma" is such a term [4, 6, 12, 24, 27, 31]. If the term "synovioma" is employed at all, it would seem reasonable to use it for a general classification of all tumors of synovial origin, including both benign and malignant lesions.

Macroscopically, synovial sarcoma is difficult to identify, since the site of origin often cannot be ascertained, and frequently connection with a synovial structure cannot be demonstrated. The usual picture is that of a seemingly sharply circumscribed tumor

* Abridgment of thesis submitted by Dr. Tillotson to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Master of Science in Orthopaedic Surgery.

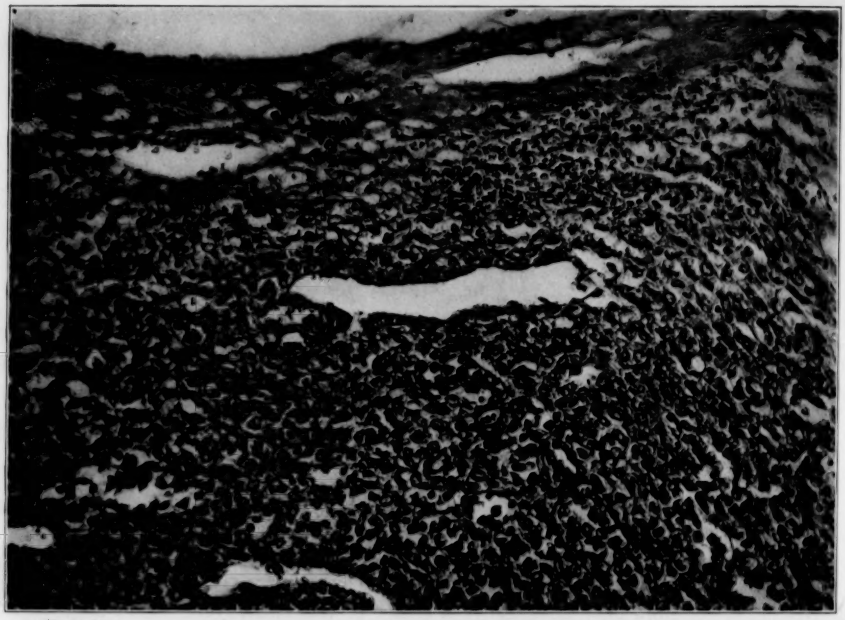


FIG. 1-A

FIG. 1-B

Case 1. The numerous tiny spaces are lined with irregular endothelioid cells; the larger spaces, fewer in number, are lined with more regular appearing endothelioid cells. (Hematoxylin and eosin, × 225.)

Fig. 1-B: A very heterogeneous structure is evident in the gross specimen.

which compresses the surrounding tissues into a pseudocapsule; this often gives the erroneous impression of benignity. Most often the color is reported to be a grayish pink, but this varies extensively from one tumor to another and may vary greatly in the same tumor. Firm attachment to a synovial structure at one point or more is common and may represent either the site of origin or of invasion. The consistency of a tumor is often varied with moderately firm areas, gelatinous areas, and, at times, friable hemorrhagic areas. Often the macroscopic spaces contain a stringy, yellowish liquid.

Microscopically, only those tumors which have one or more of the specific synovial features should be considered of synovial nature [3]. According to Bennett and to Muirhead, Kreissl, and Gordon, there are three basic patterns which indicate synovial specificity.

1. There are tissue spaces which may include spaces with a cuboidal cell lining,

usually found in some part of all tumors; slitlike spaces lined by flattened endothelial-like cells; spaces lined by indiscriminate irregular marginal cells with a frayed appearance;

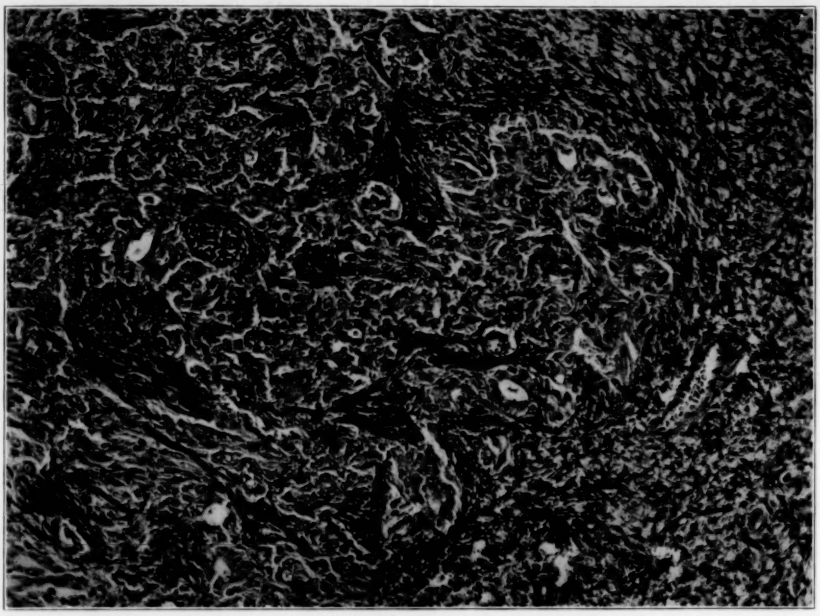


FIG. 2

Case 3. Typical tufting of the endothelial cells with portions of fibrosarcomatous appearance interspersed. There are numerous small spaces and a tendency toward clefting. (Hematoxylin and eosin, × 200.)

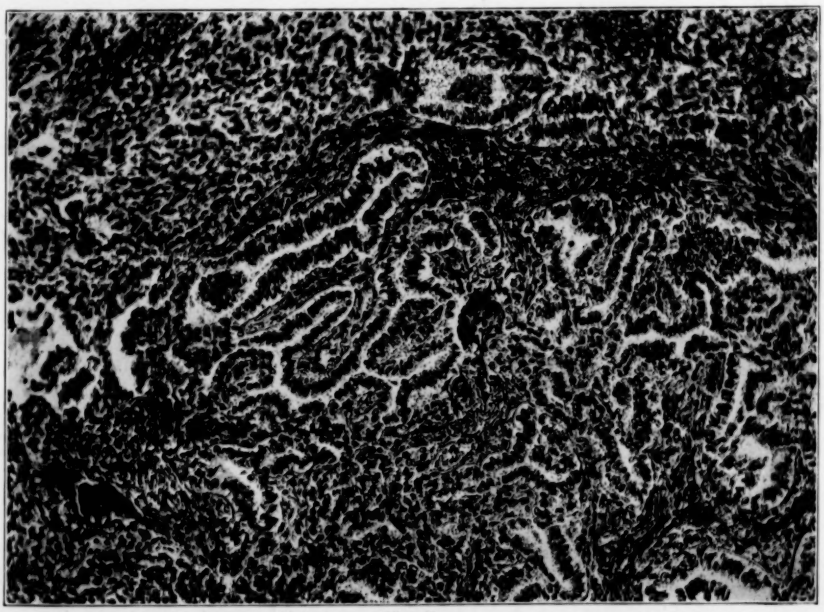


FIG. 3

Case 7. Note distinct tufting. (Hematoxylin and eosin, × 175.)

TABLE I

SUMMARY OF CASES OF SYNOVIAL SARCOMA FOUND IN LITERATURE TO DECEMBER 1, 1949 *

Author	Age	Sex	Site	Duration†	Primary Amputation	Local Excision	Local Recurrence	Secondary Amputation	Metastasis	Result ††	Total Duration
Jönsson [14]	50	F.	Wrist	4 yrs.		+		In 3 yrs.	Axilla, lungs	Died	8 yrs.
Jönsson	20	M.	Wrist	5 mos.		+				Well, 14 yrs.	
Jönsson	23	F.	Axilla	2 mos.		+	+		Lungs, spine	Died	6 mos.
Jönsson	54	M.	Shoulder	14 days		+	1 yr.		Lungs	Died	6 yrs.
Jönsson	70	F.	Thigh	5 yrs.		++	+++		Lungs	Died	9 yrs.
Jönsson	49	M.	Arm	6 mos.		+	+			Died	18 mos.
Jönsson	53	M.	Palm	4 yrs.		+	+	7 mos.	Lungs, axilla	Died	4½ yrs.
Jönsson	40	F.	Leg, groin	6 mos.		+	+		?	Died	4½ yrs.
Jönsson	14	M.	Hand	1 yr.		+			Elbow, axilla	Died	1½ yrs.
Jönsson	29	F.	Toe	8 mos.	+					Well, 18 mos.	
Jönsson	37	F.	Temporal	2 mos.		+				Well, 2 yrs.	
Jönsson	39	M.	Knee	5 yrs.		Partial	+	8 mos.	Inguinal, liver, paravertebral	Died	6 yrs.
Jönsson	37	F.	Axilla	18 mos.		+	+		Lungs, clavicle	Died	3 yrs.
Jönsson	69	F.	Hand	3 yrs.		+				Well, 1 yr.	
Jönsson	48	M.	Popliteal	25 yrs.	Refused				?	Died	27 yrs.
Jönsson	36	M.	Ankle	5 mos.		+	+	+		Well, 10 yrs.	
Jönsson	56	M.	Foot	1 yr.		+	+	+	Lungs	Died	4 yrs.
Jönsson	39	M.	Palm	3 yrs.		+	+		?	Well, 6 yrs.	
Jönsson	48	F.	Foot	40 (?) yrs		+	+	+	Spine	Died	45 (?) yrs.
Jönsson	26	F.	Ankle	4 yrs.		+				Well, 4½ yrs.	
Jönsson	23	M.	Knee	18 mos.		+	+		Lungs	Died	3 yrs.
Jönsson	25	M.	Hand	6 mos.		+			Lungs, back	?	
Karlén §	46	M.	Knee							?	
Haggart	38	M.	Knee	8 yrs.		+	+			Well, 8½ yrs.	
Moretz	60	F.	Hand	3½ yrs.		+	+	+		Died	4 yrs.
Moretz	52	F.	Arm	15 yrs.		+			?	Died	15½ yrs.
Moretz	65	F.	Knee	3 yrs.		+				Well, 11 mos.	
Moretz	12	F.	Heel	1 mo.		++	+	Twice	Chest, abdomen	Died	15 mos.
Bedrick and Zawadzki	29	M.	Thigh	2 mos.		+ Partial			?	?	
Shackman	49	F.	Elbow	1 yr.	+				Axilla	?	

TABLE I (*Continued*)

TABLE I (*Continued*)

Bennett	22	M.	Thigh	6 mos.		+				Living	
Bennett	25	M.	Thigh	5 mos.		+			Lungs	Living	
Bennett	20	M.	Tibial tubercle	3 yrs.		+				?	
Bennett	21	M.	Ankle	6 yrs.		+				?	
Bennett	30	M.	Knee	4 yrs.					Lungs	Died	49 mos.
Bennett	35	M.	Knee	?		+				Living, 54 mos.	
Bennett	22	M.	Tendo achillis	7 mos.		+	+			Living, 53 mos.	
Bennett	21	M.	Tibia	2 yrs.		++	+			Recurrence, 2 mos.	
Bennett	29	M.	Foot	Many yrs.		+				?	
Bennett	34	M.	Popliteal	6 mos.		+			Lungs	Died	11 mos.
Bennett	24	M.	Knee	6 mos.		+			Lungs	Died	23 mos.
Bennett	56	F.	Arm	2 yrs.		+				Living, 18 mos.	
Bennett	19	M.	Leg	19 days	+					?	
Bennett	25	M.	Popliteal	3½ mos.	+				Lungs	Died	12½ mos.
Bennett	24	M.	Heel	5 mos.		+		+		Living, 40 mos.	
Bennett	32	M.	Foot	2 yrs.		+	+	+	Lungs	Living, 36 mos.	
Bennett	20	M.	Tibia	2 mos.		+				Living, 24 mos.	
Bennett	23	M.	Groin	14 mos.		+				Living, 22 mos.	
Bennett	19	M.	Hand	?		+	+			?	
Bennett	30	M.	Ankle	21 mos.		Biopsy		+	Lungs	Died	29 mos.
Bennett	29	M.	Thigh	2 mos.		+				Living, 10 mos.	
Bennett	47	M.	Knee	3 yrs.		+	+	+		Living, 25 mos.	
Bennett	30	M.	Knee	17 mos.	+	Biopsy				?	
Bennett	21	F.	Trochanter	1 yr.		+				?	
Bennett	24	M.	Thigh	13 mos.		+	+		+	Died	35 mos.
Bennett	32	M.	Elbow	6 mos.		+			Lungs	Died	18 mos.
Bennett	40	M.	Ilium	6 mos.		Biopsy			Lungs	Died	?
Bennett	26	M.	Shoulder	1 mo.		+		+		?	
Bennett	31	M.	Thigh	4 mos.		Biopsy			++	Died	10 mos.
Bennett	23	M.	Elbow	6 mos.		Biopsy			++	Died	15 mos.
Bennett	35	M.	Knee	18 mos.		+				?	
Bennett	21	M.	Ankle	6 yrs.	+				Lungs	Died	6½ yrs.
Harris	61	F.	Ankle	8 mos.		+	+	+	?	Well, 1 yr.	
Harris	33	M.	Calf	2 mos.		Partial		+	?	Well, 1 yr.	

TABLE I (*Continued*)

Author	Age	Sex	Site	Duration†	Primary Amputation	Local Excision	Local Recurrence	Secondary Amputation	Metastasis	Result ††	Total Duration
Harris	37	M.	Thigh	4 mos.	+				Lungs	Died	10 mos.
Levinson *et al.*	22	M.	Thigh	9 mos.		+			Lungs	?	
Knutsson	28	M.	Wrist	5 yrs.		+	++			Living, 10 yrs.	
Knutsson	29	M.	Foot	8 yrs.		+				?	
Warren	31	F.	Foot	3 yrs.		+			?	?	
Kessel	38	F.	Ankle	2 mos.	+				Lungs	Living, 1 yr.	
Sprinz	31	M.	Thigh	4 mos.		+			Heart and intestines	Died	6 mos.
Johnson and Kearney	27	M.	Groin	3 mos.		+		+	Lungs	Living, 9 mos.	
Muirhead *et al.*	62	F.	Toe	3 mos.	+				Lungs	Died	2⅓ yrs.
Muirhead *et al.*	18	M.	Gluteal	4 mos.		+			?	Died	2½ yrs.
Muirhead *et al.*	19	F.	Knee	2 yrs.		+	+	+	?	Died	6½ yrs.
Muirhead *et al.*	43	F.	Ankle	25 yrs.		+			?	?	
Muirhead *et al.*	40	F.	Elbow	18 yrs.		+	+			Well, 3 yrs.	
Muirhead *et al.*	44	M.	Elbow	18 mos.	+					Living, 4 mos.	
Muirhead *et al.*	53	M.	Foot	8 mos.	+					Died	1⅔ yrs.
Muirhead *et al.*	20	F.	Arm	2 yrs.		+	+	+		Well, 1 yr.	
Muirhead *et al.*	31	F.	Sublingual	2 yrs.		+	+			Recurrence, 1½ yrs.	
Muirhead *et al.*	60	F.	Acromio-clavicula	3 mos.		+				Well, 1 yr.	
Muirhead *et al.*	64	M.	Leg	5 yrs.		+				Well, 1½ yrs.	
Muirhead *et al.*	39	F.	Knee	30 yrs.		+			?	?	
Muirhead *et al.*	71	M.	Foot	2 yrs.		+	+	+	Lung	Died	3 yrs.
Muirhead *et al.*	71	F.	Ankle	8 yrs.		+	+	+	?	?	
Muirhead *et al.*	?	F.	Toe	5 yrs.		+	+	+	?	?	
Muirhead *et al.*	48	F.	Knee	5 yrs.		+	+	+		Well, 10 mos.	
Muirhead *et al.*	23	F.	Hand	10 mos.		+	+			Well, 10 yrs.	
Williams and Mahaffey	35	M.	Foot	14 yrs.		+	+	+	Groin and lungs	Died	19 yrs.

* In addition to the cases tabulated by Haagensen and Stout, Geschickter and Copeland mentioned thirty-five cases, Dean Lewis mentioned five sarcomatous tumors of tendon sheaths, and Wagner listed two cases of "fibro-endothelioma" of synovial origin, but further information was not given. Hence, their cases are not included.

† Duration is the time from onset of symptoms to consultation.

†† Time listed is as of last report dated from time of treatment.

§ The cases of Jönsson and Karlén have not been tabulated previously.

spaces with a lining of multilayered cells; and spaces or clefts partly or completely lined by naked connective tissue (Figs. 1-A, 1-B, and 2). The spaces, which often resemble the

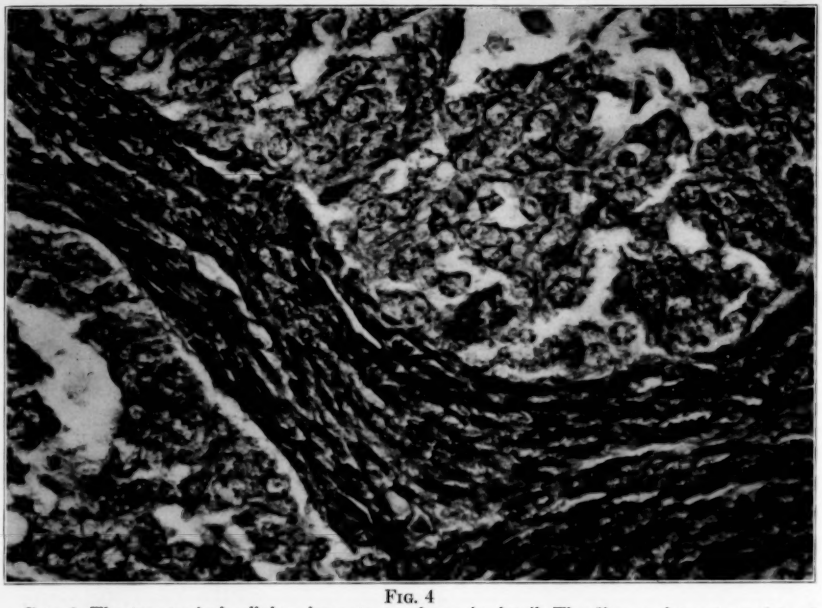


FIG. 4

Case 6. The two typical cellular elements are shown in detail. The fibrous element consists of small slender fibroblasts in narrow interlacing bundles, appearing to support the adenomatous element, which consists of large spaces lined with multicellular layers and having a glomerular appearance. (Hematoxylin and eosin, × 500.)

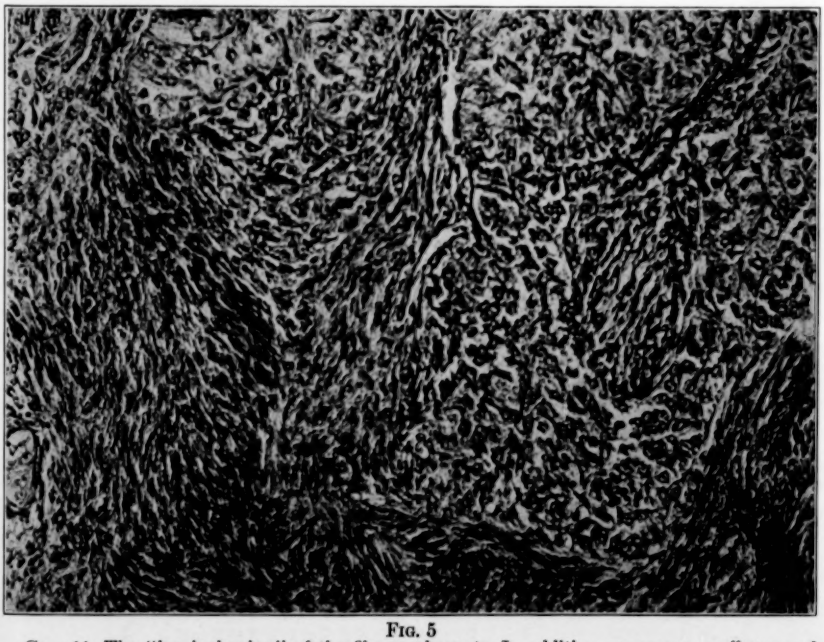


FIG. 5

Case 11. The "herringboning" of the fibrous elements. In addition, numerous small areas of calcification were seen. (Hematoxylin and eosin, × 230.)

TABLE II

SYNOVIAL SARCOMA IN MAYO CLINIC CASES

Case	Age	Sex	Site	Duration	Primary Amputation	Local Excision	Local Recurrence	Secondary Amputation	Metastasis	Result	Total Duration
1	70	M.	Knee	18 mos.	+					Well, 16 mos.	
2	39	M.	Elbow	14 mos.		+	+	+	Lungs	Died	23 mos.
3	42	M.	Calf	3 yrs.	Palliative				Lungs	Died	3¾ yrs.
4	27	M.	Popliteal	1 yr.		+				?	
5	24	M.	Heel	7 yrs.		+	+	+	Lungs	Died	9 yrs.
6	64	M.	Thigh	6 mos.		+	+		Nodes	Died	3 yrs.
7	32	F.	Groin	5 mos.		+	+		Spine	Died	4½ yrs.
8	25	M.	Axilla	8 mos.		+	+	+	Cervical cord, skin, head, neck	Died	29 mos.
9	11	F.	Thigh	9 mos.		+	+		?	?	
10	30	M.	Thigh	1 yr.		+			?	?	
11	26	F.	Greater trochanter	3 mos.		+	+		Lungs	Living, 1 yr.	
12	3	M.	Thigh and hip	2 mos.	+		+			Living, 6 mos.	
13	28	F.	Palms, wrist	7 yrs.		+	+			Living, 3 mos.	
14	45	M.	Knee	11 mos.		+	+		?	Died	5½ yrs.
15	42	M.	Elbow	18 mos.		+	+		Lungs, liver	?	
16	13	F.	Leg	1 mo.	+				Lungs, bladder	Living, 5 yrs.	
17	32	M.	Thigh	20 mos.		+	+	+	Nodes	Died	2½ yrs.
18	20	M.	Foot	18 mos.		+	+		Nodes, lungs	Died	3 yrs.
19	38	F.	Popliteal	5 yrs.		+	+		Pelvis, lungs	Died	5¾ yrs.
20	68	M.	Knee	20 yrs.		+			Nodes	Living, 3 yrs.	
21	2	M.	Popliteal	4 mos.		Biopsy			Nodes	Died	5 mos.
22	24	F.	Heel	10 yrs.		++++	++++		Nodes, lungs	Died	13 yrs.
23	53	F.	Thigh and hips	5 yrs.		++	+		Flanks ?	Living, 19 yrs.	
24	54	M.	Thigh	2 yrs.		+			Lungs	Living, 5 yrs.	
25	23	F.	Forearm	3 yrs.		+	+	+	Nodes	Died	38 mos.
26	16	F.	Hand	18 mos.		++	+	+	Lungs	Died	3½ yrs.
27	1 mo.	F.	Foot	1 mo.		+				Living, 20 yrs.	
28	16	F.	Hand	11 mos.		+	+	+	Flank	Living, 6 mos.	
29*	32	M.	Greater trochanter	1½ yrs.		+ (End radium)			Lungs	Died	2¼ yrs.
30*	20	M.	Ankle	1½ yrs.		+ (Partial and palliative roentgenotherapy)			Lungs	Died	35 mos.
31*	2½	F.	Forearm	1 yr.		++	++		Axilla, lungs	Died	22 mos.

* These three cases were found after our study was completed, and so are added to the tabulation of cases, but are not included in the statistical analysis.

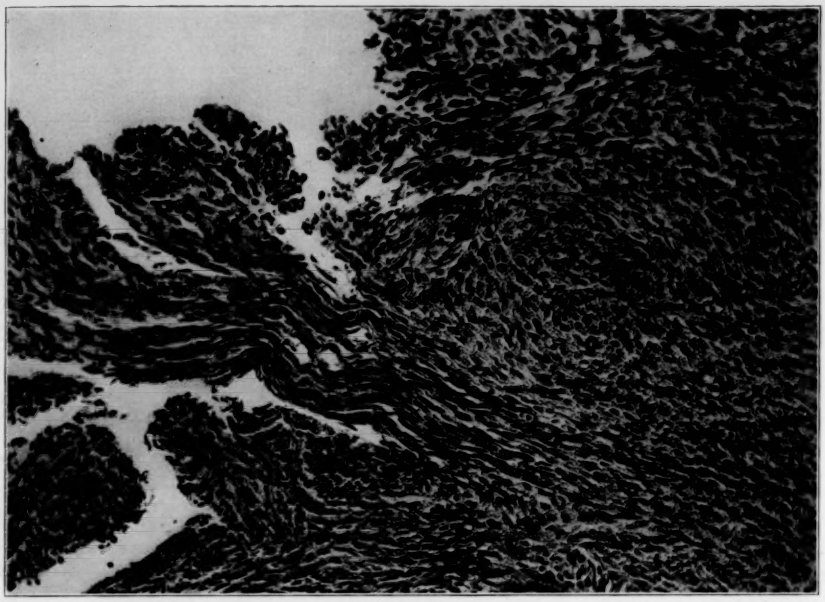


FIG. 6

Case 28. Fibroblasts largely arranged in interlacing bundles with some clefting and numerous small spaces. In a few places clumping of thicker ovoid cells can be seen. (Hematoxylin and eosin, × 200.)

tearing of tissue similar to that caused by artifacts, appear with characteristic frequency in synovial tumors.

2. Cell tufts (Figs. 2 and 3) are present. They vary from compact groups of oval or polygonal cells to villous projections into the glandlike spaces (Figs. 3 and 4).

3. Pavements of epithelial-like cells appear on a supporting stroma of compact elongated cells with small dark nuclei (Figs. 5 and 6).

The fibrosarcomatous portions characteristically show a tassel-like arrangement of the collagenous fibers (Fig. 5) and a herringbone pattern of interlacing bundles of short, plump, spindle-shaped cells (Figs. 4 and 6).

There is no typical history for synovial sarcoma. As a rule the course is long and insidious, often with repeated local excisions of the tumor followed by recurrences; sooner or later, however, the tumor spreads either to the regional nodes or the lungs, or to both. Pain, disability, and the results of physical examination are so variable as to be unreliable in making the diagnosis. Even macroscopic examination at operation does not reveal anything which can be considered typical. Consequently, diagnosis can be made only after microscopic examination of a specimen removed for biopsy.

Budd sounded the keynote of treatment when he said: "The belief that an extremity could always be removed if there were recurrence did not delay the development of lung metastases." Results of treatment of synovial sarcoma have been poor. Local excision does not suffice, even if radical. Roentgenotherapy may temporarily allay the symptoms due to metastasis and may even cause a temporary regression, but the outcome is unchanged. Metastasis to the skin, liver, paravertebral areas, retroperitoneal areas, bladder, intestines, heart, spinal column and clavicle also has been reported.

ANALYSIS

Table I presents, in the tabular form employed by Haagensen and Stout, ninety

TABLE III

INCIDENCE OF SYNOVIAL SARCOMA ACCORDING TO AGE AND SEX

Age (*Years*)	All Cases			Mayo Clinic Cases		
	Male	Female	Total	Male	Female	Total
0 to 9	5	1	6	2	1	3
10 to 19	11	12	23	0	4	4
20 to 29	53	23	76	4	4	8
30 to 39	32	18	50	3	2	5
40 to 49	20	9	29	3	0	3
50 to 59	8	7	15	1	1	2
60 to 69	6	8	14	2	0	2
70 to 79	3	3	6	1	0	1
Unknown			3(1%)			
Totals	138	81	222*	16	12	28
Per cent.	63	36	100*	57	43	100

* This includes the 3 cases (1 per cent.) in which facts were unknown.

additional cases reported in the literature to December 1949. These ninety cases, together with those listed by Haagensen and Stout, make a total of 194 cases already reported. Table II presents in similar form twenty-eight cases from the Mayo Clinic. Tables III, IV, V, and VI summarize, as indicated, data obtained from the 222 cases now reported in the literature and from the series of twenty-eight Clinic cases alone. The cases of Jönsson [15] and of Karlén appear to have been overlooked in previous tabulations, but are included in the present report. The other sixty-seven cases have appeared in the literature since the publication of the paper by Haagensen and Stout. Prior tabulations were made by Knox, DeSanto, Tennant and Rosahn, and Lazarus and Marks. Haagensen and Stout tabulated 104 cases from the literature which they considered acceptable, but

TABLE IV

DISTRIBUTION IN VARIOUS SITES

Site	All Cases		Mayo Clinic Cases	
	Number	Per cent.	Number	Per cent.
Knee and popliteal space	72	32.4	6	21.4
Foot	29	13.1	4	14.3
Thigh	26	11.7	6	21.4
Ankle	19	8.6	0	
Hand	16	7.2	3	10.8
Elbow	16	7.2	2	7.1
Leg	9	4.1	2	7.1
Wrist	8	3.6	0	
Groin	6	2.7	1	3.6
Pelvis and hip	5	2.3	2	7.1
Arm	4	1.8	0	
Axilla	4	1.8	0	
Shoulder	3	1.3	1	3.6
Forearm	2	0.9	1	3.6
Head and neck	2	0.9	0	
Unknown	1	0.4		
Totals	222	100.0	28	100.0

FIG. 7

Case 2. A mass arises directly from the synovial membrane by a pedicle. Note the tendency toward tufting or alveolar formation. (Hematoxylin and eosin, × 110.)

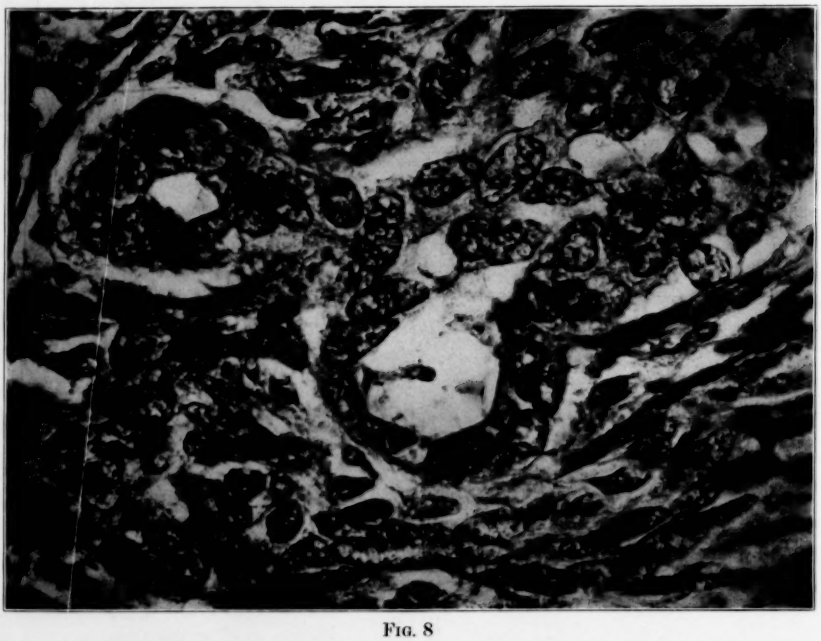


FIG. 8

Case 5. Two cell types are distinctly shown. The small fibroblasts are most prominent in a herringbone pattern; the larger round or oval cells occur in multiple cell layers, often forming glandular spaces which contain mucin. (Hematoxylin and eosin, × 750.)

TABLE V

DURATION OF SYMPTOMS BEFORE PATIENT SOUGHT MEDICAL AID

Duration	All Cases	Mayo Clinic Cases
Unknown	8	0
0 to 6 months	69	7
7 to 12 months	34	5
13 to 18 months	13	5
19 to 24 months	6	2
2 years	20	1
3 years	18	2
4 years	10	0
5 years	15	2
6 or more years	29	4
Totals	222	28

the authors have added all cases reported since that tabulation without a critical analysis of each case. In each instance we have based our calculations on the number of cases for which the necessary information was available.

The average age in the authors' series of twenty-eight cases was 30.9 years (33.5 years for all cases). About 54 per cent. of the patients were less than thirty years of age when seen at the Clinic; 71.4 per cent. were less than forty years of age. Only 18 per cent. of the patients were fifty or more years of age. This corresponds fairly well with figures of 47.9 per cent., 70.8 per cent., and 16 per cent., respectively, for all cases. The four most frequent sites of synovial sarcomata were the knee with popliteal space, foot, thigh, and hand, in the order named (a total of 67.9 per cent. of our cases); the pelvis and hip, leg, and elbow ranked in fifth place at 7.1 per cent. each. The four commonest

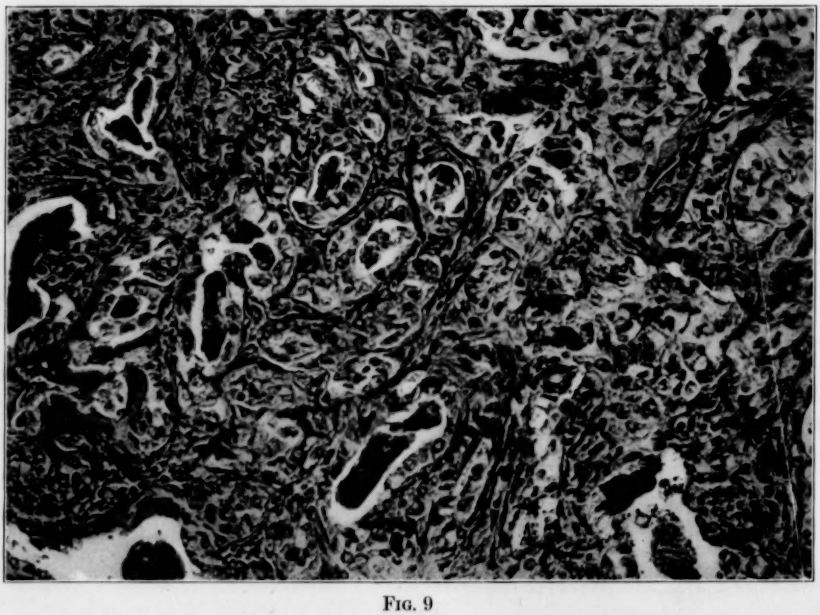


FIG. 9

Case 8. Distinct tufting is present. In most of the spaces there is a homogenous substance. Most of the tumor was composed of small interlacing fibroblasts; only a few areas showed this characteristic adenomatous picture. (Hematoxylin and eosin, × 225.)

TABLE VI

KNOWN RESULTS AFTER SURGERY

Time after Surgery	All Cases		Mayo Clinic Cases	
	Dead	Living	Dead	Living
0 to 6 months	14	11	2	3
7 to 12 months	19	21	4	1
13 to 18 months	6	15	1	1
19 to 24 months	6	4	2	0
2 years	6	6	2	0
3 years	10	7	1	1
4 years	8	3	2	0
5 years	3	2	0	2
6 to 10 years	17	8	0	0
11 to 15 years	2	1	0	0
16 to 20 years	0	2	0	2
Totals *	91	80	14	10

* Of the cases reported in the literature, results after surgery are not known in 51; of the cases treated at the Mayo Clinic, results are not known in 4.

sites of all cases studied were the knee, foot, thigh, and ankle, with the hand and elbow tying for fifth place. Lesions in these sites totaled 80.2 per cent. of all lesions (Table IV).

The average duration of symptoms of the authors' twenty-eight patients up to the time they were seen at the Clinic was 2.78 years, the average for the reported cases from onset to consultation being 3.2 years. Of our patients, 68 per cent. had had symptoms for less than two years; the corresponding figure for the reported cases is 57 per cent. Ten per cent. of the patients seen at the Clinic had had symptoms for two to five years; about 22 per cent. reported complaints of five years and longer (Table V). Similarly, the reported cases showed that, in 22.4 per cent., patients had had symptoms for two to five years, and in 20.6 per cent. symptoms had been present for five years or longer.

Analysis of our latest reports reveals that all deaths in Mayo Clinic cases occurred within five years after operation (Table VI); according to follow-up reports on all cases, 79.1 per cent. of the deaths occurred within five years after operation. Of fourteen Mayo Clinic patients living at last report, 60 per cent. were known to have metastasis; 30.4 per cent. is the corresponding figure for all cases reported in the literature. The over-all duration of tumors which resulted in death in our cases averaged 4.5 years; the average for all reported cases was 5.4 years.

Concerning the two long-term survivals in our series, one patient (Case 27) first was seen at the Clinic at the age of one month with a tumor on the dorsum of the foot which had been present at birth. It was excised locally and widely; the diagnosis was perilymphangiofibrosarcoma. After healing had taken place, the foot was treated with radium. At last report the affected limb was three inches (7.62 centimeters) shorter, and considerable atrophy of the foot and leg had taken place. The other patient (Case 23) was seen first at the Clinic in 1930. She had a soft-tissue tumor over the left ilium about the size of an adult's head. It was widely excised locally and seven radium treatments were administered. In 1943, when the patient was seen again, she had a recurrent tumor the size of an egg in the same region. Again it was excised, but that time a course of roentgenotherapy was administered. At last report her health was "about as usual" and further recurrences were denied.

Two other patients are living five years after treatment; each is known to have pulmonary metastasis and one has metastasis to the bladder in addition. Cell patterns typical

of those mentioned earlier were present in specimens of tumor tissue which were examined (Figs. 7, 8, and 9).

SUMMARY AND CONCLUSIONS

Synovial sarcoma is a rare tumor. Almost three-fourths of all patients having these tumors are less than forty years of age and about half of them are less than thirty years of age. The most frequent sites are the knee, foot, thigh, ankle, hand, and elbow, in the order mentioned.

The course tends to be long, and the patient often undergoes repeated local excisions and continues to have recurrences even after many years. The tumor is highly malignant and spreads readily to regional nodes, to the lungs, or to both. Consequently the prognosis is poor. Only one of our patients has survived five years or more after operation without recurrence or metastasis.

REFERENCES

1. Bedrick, J. J., and Zawadzki, S. A.: Malignant Synovioma. Case Report. Milit. Surgeon, **97:** 374–377, 1945.
2. Bennett, G. A.: Malignant Neoplasms Originating in Synovial Tissues (Synoviomata). A Study of Thirty-two Specimens Registered at the Army Institute of Pathology During the War-Time Period, 1941–1945. J. Bone and Joint Surg., **29:** 259–291, Apr. 1947.
3. Berger, Louis: Synovial Sarcomas in Serous Bursae and Tendon Sheaths. Am. J. Cancer, **34:** 501–539, 1938.
4. Briggs, C. D.: Malignant Tumors of Synovial Origin. Ann. Surg., **115:** 413–426, 1942.
5. Budd, John: Sarcoma of Soft Tissues. California Med. **67:** 249–251, 1947.
6. Coley, B. L., and Pierson, J. C.: Synovioma. Report of Fifteen Cases with Review of Literature. Surgery, **1:** 113–124, 1937.
7. DeSanto, D. A.; Tennant, Robert; and Rosahn, P. D.: Synovial Sarcomas in Joints, Bursae, and Tendon Sheaths. A Clinical and Pathological Study of Sixteen Cases. Surg., Gynec., and Obstet., **72:** 951–981, 1941.
8. Geschickter, C. F., and Copeland, M. M.: Tumors of Bone, Ed. 3, p. 695. Philadelphia, J. B. Lippincott Co., 1949.
9. Haagensen, C. D., and Stout, A. P.: Synovial Sarcoma. Ann. Surg., **120:** 826–842, 1944.
10. Haggart, G. E.: Synovioma of the Knee Joint. A Case Report. J. Bone and Joint Surg., **24:** 438–442, Apr. 1942.
11. Harris, V. C. J.: Three Cases of Synovioma. British Med. J., **1:** 447–448, 1948.
12. Jaffe, H. L., and Lichtenstein, Louis: Synovial Sarcoma (Synovioma). Bull. Hosp. Joint Dis., **2:** 3–10, 1941.
13. Johnson, F. H., and Kearney, E. A.: Sacro-Iliac Disarticulation (Hemipelvectomy), Report of a Case. U. S. Naval Med. Bull. **49:** 110–112, 1949.
14. Jönsson, Gunnar: Malignant Tumors of the Skeletal Muscles, Fasciae, Joint Capsules, Tendon Sheaths and Serous Bursae. Acta Radiol., Supplementum 36, 1938.
15. Jönsson, Gunnar: Points Regarding Synovial Fibrosarcoma. Acta Radiol., **29:** 356–357, 1948.
16. Karlén, Anders: Fall av synovialom i knäleden. Nord. Med., **16:** 3705–3707, 1942.
17. Kessel, A. W. L.: Synovioma of Right Ankle Region. Proc. Royal Soc. Med., **41:** 383–386, 1948.
18. Kling, D. H.: The Synovial Membrane and the Synovial Fluid with Special Reference to Arthritis and Injuries of the Joints. Los Angeles, Medical Press, 1938.
19. Knox, L. C.: Synovial Sarcoma. Am. J. Cancer, **28:** 461–480, 1936.
20. Knutsson, Folke: Two Synovial Fibrosarcomas (Jönsson). Acta Radiol., **29:** 4–6, 1948.
21. Lazarus, J. A., and Marks, M. S.: Synovial Sarcoma with Report of Two Cases. Surgery, **13:** 290–308, 1943.
22. Levinson, L. J.; Harris, J.; and Singer, M.: Newark Beth Israel Hospital Cancer Conference. I. Sarcoma of Soft Parts. J. Med. Soc. New Jersey, **45:** 76–79, 1948.
23. Lewis, Dean: Tumors of the Tendon Sheaths. Surg., Gynec., and Obstet., **59:** 344–349, 1934.
24. Lewis, R. W.: Roentgen Diagnosis of Pigmented Villonodular Synovitis and Synovial Sarcoma of the Knee Joint. Preliminary Report. Radiology, **49:** 26–38, 1947.
25. Moretz, W. H.: Malignant Tumors Arising from the Synovial Membrane with Report of Four Cases. Surg., Gynec., and Obstet., **79:** 125–132, 1944.
26. Muirhead, E. E.; Kreissl, L. J., Jr.; and Gordon, C. E.: Synovial Sarcoma and Relatively Benign Synovioma. Texas State J. Med., **45:** 202–209, 1949.

27. Murray, M. R.; Stout, A. P.; and Pogogeff, I. A.: Synovial Sarcoma and Normal Synovial Tissue Cultivated *in Vitro*. Ann. Surg., **120**: 843–851, 1944.
28. Shackman, Ralph: Malignant Synovioma of the Left Elbow. Proc. Royal Soc. Med., **40**: 273–275, 1947.
29. Smith, L. W.: Synoviomata. Am. J. Pathol., **3**: 355–364, 1927.
30. Sprinz, Helmuth: A Case of Synovial Sarcoma With Metastases. Bull. U. S. Army Med. Dept., **9**: 131–140, 1949.
31. Stanford, S., and Horne, E. A.: Malignant Synovioma. J. Bone and Joint Surg., **25**: 883–891, Oct. 1943.
32. Wagner, L. C.: Malignant Tumor of Synovial Membrane of Knee-joint. Excision; Recurrence; Second Excision and Post-operative Treatment. Ann. Surg., **101**: 809–810, 1935.
33. Warren, Shields: Synovial Sarcoma of the Soft Tissue of the Leg. J. Missouri State Med. Assn., **45**: 351–354, 1948.
34. Williams, R. D., and Mahaffey, H. W.: Synovioma: A Case Report with Pulmonary Metastases that Regressed Following Irradiation. Ohio State Med. J., **45**: 988–990, 1949.

TITANIUM, A METAL FOR SURGERY

BY GOTTLIEB S. LEVENTHAL, M.D., PHILADELPHIA, PENNSYLVANIA

From the Department of Research, Mount Sinai Hospital, Philadelphia

Vitallium and SMo stainless steel have been used for several years; both alloys have usually been found to be satisfactory for the fixation of fractures. At times, however, the work of the surgeon has been ruined by screws becoming loose, even without infection, prior to the complete organization of the fracture; at other times, screws and plates have been broken, nullifying the attempts at fixation of a fracture.

Clay Ray Murray [2], in reporting for the Committee on Fractures and Other Traumas, of the American College of Surgeons, stated: "The ideal metal for use in the fixation of fractures . . . would be a metal having the physiologically inert characteristics of Vitallium, the mechanical and physical characteristics of the SMo metal". Bothe, Beaton, and Davenport, testing various metals implanted in laboratory animals, found that "the response of bone to titanium was as good, if not better, than to the non-corrosive alloys, in that there was more tendency for the bone to fuse with it". Titanium * has been known as an element for over a century and a half, but it has been very difficult to extract for commercial purposes. At the present time, extraction of the metal is being carried out more extensively, and there promises to be a fairly good supply within a short time at a reasonable price.

Titanium has a tensile strength of 75,000 pounds per square inch and a yield strength of 50,000 pounds per square inch. These properties of titanium are almost identical with those of SMo stainless steel. Titanium is silver-white in color; its weight is about 60 per cent. that of stainless steel, and it is about 60 per cent. heavier than aluminum. It machines in about the same way as stainless steel, and it can be forged and welded. Titanium is highly resistant to corrosion.

Stainless-steel plates and screws have to be handled very carefully; for, if nicks are produced, eddy currents will develop when they are used in the tissues. Since titanium is an element, there is no chance of eddy currents developing, and one does not have to be so

* Titanium was supplied through the courtesy of Remington Arms Co.

careful. Screws with nicks in them, however, should be discarded, for such a mechanical imperfection will not produce clean threads in the bone.

Soft-tissue reaction to titanium was studied by implanting bars of known weight and size into the subcutaneous tissue layer of the dorsal aspect of rabbits. The subcutaneous tissue was examined at intervals of two, four, six, eight, and ten weeks. At no time was there any evidence of induration. At the end of two weeks, a glistening, but slightly cyanotic, synovial-like layer was found at the site of the implant. Study of the tissue revealed nothing that could account for this discoloration. In subsequent weeks, the glistening layer was still present, but the cyanotic appearance had entirely disappeared. A microscopic examination revealed a flattened layer of endothelial-like lining similar to what one would find on the exposed serous surface of any joint. No reaction to the metal was found. The subcutaneous tissue presented a perfectly normal appearance, except for the flattened layer of cells. The walls of the "cyst" enclosing the implant could be gently glided over the titanium implant, but an excess of fluid in the cavity was not found.

Bone reaction was studied by the insertion of 0–80 screws into the femora of rats. A hole was first drilled, and the screw was then inserted. The animals were sacrificed at six, twelve, and sixteen weeks. In no animal was there any infection, induration, or discoloration about the site of the screw in the soft tissues. The site at which the screw was inserted was not enlarged with excessive bone, and the screw head remained outside the bone just as it had been inserted. At the end of six weeks, the screws were slightly tighter than when originally put in; at twelve weeks, the screws were more difficult to remove; and at the end of sixteen weeks, the screws were so tight that in one specimen the femur was fractured when an attempt was made to remove the screw. Microscopic examinations of the bone structure revealed no reaction to the implants. The trabeculation appeared to be perfectly normal.

Flat plates of titanium were studied for weight loss by insertion into the subcutaneous tissue layer of rabbits. The average bar presented a surface of 7.5 square centimeters. After two and one-half months the amount of loss was .0002 gram. This weight loss is insignificant and is really within the limit of error in weighing.

From these studies it would appear that titanium is a metal which may be useful in surgery, because of its strength and its failure to cause tissue reaction. The fact that bone becomes attached to titanium may be a disadvantage in cases where screws or pins are placed temporarily. In the past, the use of some prostheses has not become popular because it has been felt that these would remain separate from the bone and eventually loosen. Since titanium adhers to bone, it may prove to be an ideal metal for such prostheses. Some plates and screws have been used in humans with no reaction clinically or as shown by roentgenograms. A titanium plate one-sixteenth of an inch in thickness is partially radiolucent to roentgen rays. This radiolucency may be an advantage in some cases.

SUMMARY

Studies on titanium made by implanting into subcutaneous tissue of rabbits, and femora of rats, have demonstrated that titanium is an inert metal which appears to be ideal for fixation of fractures. A sufficient number of plates and screws have not been used to determine whether or not they will break in the treatment of fractures. It is hoped that eventually plates and screws can be produced which will not readily break.

NOTE: The author wishes to express gratitude to Dr. David R. Meranze, Pathologist at Mount Sinai Hospital, for his kindness in preparing and examining the microscopic sections.

REFERENCES

1. BOTHE, R. T.; BEATON, L. E.; and DAVENPORT, H. A.: Reaction of Bone to Multiple Metallic Implants. Surg., Gynec., and Obstet., **71**: 598–602, 1940.
2. COMMITTEE ON FRACTURES AND OTHER TRAUMAS, American College of Surgeons, Proc. Twenty-third Annual Meeting, Atlantic City, New Jersey, January, 1945.

SKIN-TIGHT CASTS FOR TREATMENT OF CLUB-FOOT

BY J. WARREN WHITE, M.D., HONOLULU, HAWAII, AND
COMMANDER WILLIAM H. GULLEDGE, *Medical Corps, United States Navy*

From the Shriners' Hospital for Crippled Children, Honolulu

The conservative treatment of congenital talipes equinovarus is usually the wedged-cast method, described by Kite, or the splint method of Denis Browne. Excellent results have been reported from the use of either of these methods,—Kite reports successful treatment in 90 per cent. of his cases.

There are certain disadvantages associated with both methods: the Kite cast requires frequent wedging, which involves many trips to the hospital on the part of the patient, and time-consuming, meticulous care on the part of the physician in taking the wedge and applying the casts. It also requires the plaster to be extended above the knee to prevent the cast from slipping off in the earlier stages of correction. The Denis Browne splint requires almost constant attention, for the adhesive strapping must be changed every five to seven days, entailing frequent hospital trips or long periods of hospitalization at considerable expense.

The method of treatment to be described is the use of skin-tight casts with sponge-rubber pads which maintain, without wedging, a corrective kinetic force for two weeks or more. We believe it has unique advantages.

The skin of the foot and ankle is painted with compound tincture of benzoin or an adherent. With one hand, an assistant holds the foot by the toes in the desired position, and with the other hand he holds the leg just above the knee, with the knee flexed. Three pads of quarter-inch thick sponge rubber are cut, usually one and one-half inches square for the newborn and varying for older children with the size of the foot to be treated. These pads are placed next to the skin,—one over the medial side of the first metatarsophalangeal joint, running proximally a little; one over the sinus tarsi and cuboid on the lateral side of the foot; and one just back of the heel. These are held in place by the sticky adherent, which also prevents the short plaster from slipping. A circular, skin-tight plaster cast is then applied from the tips of the toes to just below the knee. As the plaster is setting, the surgeon grasps the foot as shown in Figures 1 and 2, the left hand for the left foot, and the right hand for the right foot. The thumb passes under the sole, with the ball of the thumb under the cuboid, the index finger across the dorsum, and the long finger behind the heel. With this grasp, the surgeon has excellent control of all three components in the deformity of the foot, and he may mold the plaster and correct at the same time, using the free hand to assist and smooth the plaster. After the plaster has set, a short length of elastic bandage is wrapped around the top of the cast to "get rid of the edge of the cast". The completed cast is shown in Figure 3. It is felt that not only is it unnecessary to carry the cast above the knee, but also that the employment of the thigh element with a flexed knee to gain an external rotation correction of the leg constitutes an unwarranted strain on the knee.

During the period of active correction, the cast is changed only at two-week intervals. It is usually true that the foot which has not been previously treated is completely corrected at the end of six to seven plaster changes, and the last plaster is allowed to remain on for from three to four weeks as a holding plaster.

The principles and sequence of correction as laid down by Kite are followed. As a matter of record, all feet are examined by means of roentgenograms, regardless of the patient's age, before treatment is started. The adduction of the fore part of the foot is corrected first, followed by correction of the inversion. This stage is usually reached at the

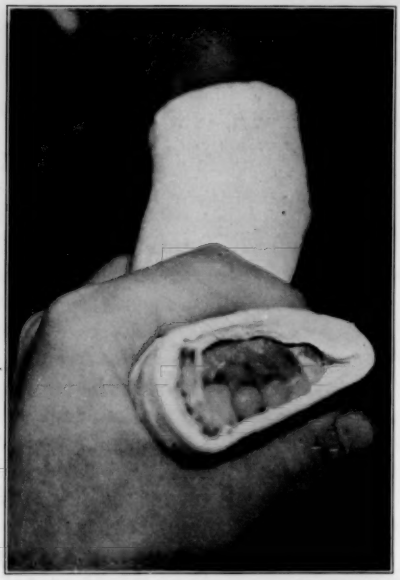


FIG. 1

FIG. 2

FIG. 3

Fig. 1: Shows how the cast is held while molding and correcting. Note how the thumb-web pressure corrects the adduction, while the thumb and index finger correct the varus of the fore part of the foot.

Fig. 2: Illustrates thumb pressure under the cuboid while correcting equinus.

Fig. 3: The completed cast. Note the sponge-rubber pad along the medial side of the first metatarsophalangeal joint; also the relative size of foot and sponge-rubber pads.

end of the fourth or fifth plaster change. Clinically, when the adduction has been corrected, the foot remains in abduction when allowed to hang down; and, when the child attempts dorsiflexion, it is pulled up and out by the common extensor tendon rather than being pulled in and up by the anterior tibial tendon. After full correction has been obtained, special attention is paid to developing muscle action to correct the muscle imbalance and discourage recurrence.

Unless the adduction and the varus are taken care of before the correction of the equinus is attempted, it will be difficult to manipulate the foot into dorsiflexion; and a convex plantar deformity in the mid-tarsal joint known as a "rocker-bottom" will develop. Consequently, roentgenograms are taken before correction of the equinus is attempted. If the adduction has been corrected, the mid-line of the talus points toward the first metatarsal in the anteroposterior view. If the inversion has been corrected, the calcaneus and talus will be shown to be separated at their anterior ends, forming an angle of about 30 degrees in the anteroposterior view.

FIG. 4-A

FIG. 4-B

Shows typical case before and after treatment.

If these conditions appear, then correction of the equinus is easy and is usually accomplished in two or three plaster changes. It should be emphasized that the pressure must be exerted under the cuboid and not against the heads of the metatarsals. If resistance is felt to be great, or a rocker-bottom begins to develop, it is imperative that the situation be reviewed, both clinically and roentgenographically, as it will usually be found that the varus and the adduction have not been completely corrected.

At the completion of the plaster treatment, it is the authors' practice to hold the feet in the overcorrected position by means of a crossbar attached to the soles of the shoes, the right and left shoes are interchanged. This splint is worn continuously until the child reaches walking age, at which time he is fitted with corrective shoes, the splint being worn only at night.

Figures 4-A and 4-B show a patient before and after treatment.

In this Clinic a total of thirty-five cases of club-foot have been treated by this method during the past seven months. Of these cases, twenty-one had not been treated previously, and fourteen were recurrent. Nineteen cases were bilateral and sixteen cases unilateral, making a total of fifty-four feet. In the previously untreated cases, the results are considered excellent, and in the recurrent cases the results are considered good. No patient has required manipulation of the club foot under anaesthesia, although one patient with recurrent bilateral club-foot required a wedge osteotomy of the right foot to correct a persistent and marked adduction deformity.

In the total of 378 skin-tight casts which have been applied, only two small pressure sores developed. Both of these were healed at the next change of plaster. In spite of the fact that this is a below-the-knee cast, no cast has slipped down, losing or distorting corrective forces, as the padded cast is prone to do.

We believe that this method of applying casts has the following advantages:

1. The sponge-rubber pads over the three pressure points exert a constant corrective force between plaster changes and act as protection against pressure sores.

2. The danger of the cast slipping and distorting the corrective forces does not exist, even though the plaster is not carried above the knee.

3. Hospital visits are required only every two weeks, thus saving time and expense on the part of the patient, and time on the part of the physician.

4. A minimum of care is demanded of the parent between visits to the hospital.

5. The cast is easily and quickly applied and removed, requiring no special skill on the part of the surgeon. It can either be soaked off or be removed by a small rongeur or a small sequestrum forceps. The conventional cast cutter is of course too large. The new reciprocating electric cast cutter must not be used for obvious reasons.

REFERENCES

BROWNE, DENIS: Modern Methods of Treatment of Club-Foot. British Med. J., **2**: 570–572, 1937.

KITE, J. H.: The Treatment of Congenital Club-Foot. Surg., Gynec., and Obstet., **61**: 190–200, 1935.

TRANSPLANTATION OF THE TIBIAL TUBERCLE

BY DUNCAN C. MCKEEVER, M.D., F.A.C.S., HOUSTON, TEXAS

There are several conditions in which change in position of the insertion of the patellar tendon is desirable. Recurrent dislocation of the patella is probably the one most frequently encountered. A method of doing this by intrinsic internal fixation is here presented. The method requires no metallic fixation whatever, and immediate unsupported full weight-bearing can be permitted and is desirable.

After exposure of the patellar tendon and tibial tubercle, a rectangular cut is made in the periosteum, outlining the insertion of the patellar tendon. The two sides of this rectangle are cut vertically with a motor saw. The proximal end is also cut vertically with the motor saw if a straight-blade, reciprocating type of saw is being used. It can be cut with an osteotome. The distal end of the rectangle is then cut at an angle of 45 degrees in the distal direction. To remove the block of bone the proximal end must be pried up and the undercut distal end pulled out. The site of the new insertion is then selected and a slightly smaller block of bone is removed at this point, the first block being used as a pattern. The block of bone with the patellar-tendon insertion can then be put in place only by inserting the distal end first, with the block in a vertical position, and then pressing or driving in the proximal end. The block of bone from the new position is inserted into the old site of the tibial tubercle. It is readily apparent that it is impossible for any pull exerted by the quadriceps muscle to dislodge this block of bone into which the patellar tendon is inserted.

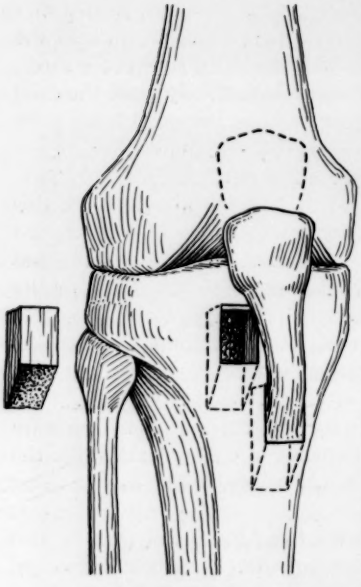


FIG. 1

Full flexion of the knee is immediately possible; full weight-bearing can be permitted the following day with no more support than an elastic bandage; a normal range of motion is rapidly obtained. The accompanying illustration (Fig. 1) enables one to readily visualize the mechanics of this transposition and to understand why any plate, screw, or bolt is entirely superfluous.

This operative procedure has been successfully carried out and early ambulation has been permitted in eleven knees in seven different patients, for three different clinical conditions.

In two of these cases, the diagnosis was bilateral recurrent dislocation of the patella. These cases were very similar, except that one patient was nineteen years of age and one was thirty-three.

The latter patient had had recurrent dislocation of the patella bilaterally for at least fifteen years. In the year immediately preceding the operation the left knee had become dislocated at the slightest provocation. Examination revealed marked torsion and bowing of the tibia on both sides. The patellae were about one to one and one-half inches higher than the normal position. The line of the direct pull of the quadriceps crossed the knee joint lateral to the mid-line of the femoral condyles. Both patellae were peculiarly shaped in that they were somewhat wedged toward the lower end. On November 10, 1947, the operation described above was carried out on both knees. Four days later, the patient was

able to walk alone in a stiff-leg position, the only protection being an elastic bandage applied at the knee. Voluntary flexion and extension exercises were started at once. The patient was ambulatory when dismissed from the hospital on December 1, 1947. By December 15, 1947, approximately five weeks after the operation, he had 110 degrees of flexion in the right knee and 80 degrees in the left knee. On January 5, 1948, slightly less than eight weeks from the time of the operation, he had an almost complete range of motion in the right knee, and about 100 degrees of motion in the left knee. He was walking well, was able to dance, and could drive his own car. Physical therapy was discontinued. These knees are now functionally normal.

The other case of bilateral dislocation was very similar, except that the patient, being younger and a somewhat loose-jointed individual, acquired a full range of motion in both knees in less than six weeks. This was the first case in which this technique was used; it was done in 1943.

Another clinical condition in which this operative procedure has been used is cerebral palsy with flexion contracture of the knees. This technique has been used successfully in two bilateral cases.

Still another condition in which this operative procedure has been used in a slightly modified way is Schlatter-Osgood disease. In more severe and advanced cases of this condition, it is very difficult for the patient to do any work which involves getting down on the knees. The patella is displaced upward, so that the weight is borne directly on the enlargement at the tibial tubercle instead of on the patella. The tenderness of the tibial tubercle may frequently persist in these cases long after the final and complete closure of the epiphyses.

If the patella is markedly displaced upward, the operative procedure can be carried out exactly as described, the advancement being in a distal direction and of sufficient length to return the patella to normal position. This procedure was successfully applied in one such case.

If the patella is displaced upward less than three-fourths of an inch and if it is impossible to advance the tibial tubercle in a distal direction to a sufficient degree to permit its firm fixation without moving the patella too far distally, the following modification of this procedure may be used. It has been successfully carried out in two cases. Instead of undercutting the lower end of the tibial tubercle, a long point is cut on it, so that the entire piece of bone to be moved is approximately two inches in length. This piece is then turned up on end and driven into the upper end of the hole from which it was removed. It is driven directly into the cancellous bone in the upper end of the tibia and is slightly countersunk so as to produce a smooth surface with no projection. This procedure will lower the patella about one-half to three-fourths of an inch, the exact amount varying slightly with the position and angle at which the free tibial tubercle is driven into the upper end of the tibia.

Both of these patients were permitted to bear weight immediately without external support. Symptoms were relieved, and a full range of motion was rapidly obtained.

THE USE OF MUSCLE RELAXANTS AS AN AID IN THE DIAGNOSIS AND THERAPY OF ACUTE LOW-BACK DISORDERS *

BY EDWARD B. SCHLESINGER, M.D., AND FRANK E. STINCHFIELD, M.D., NEW YORK, N. Y.

From the Departments of Neurological Surgery and Orthopaedic Surgery, College of Physicians and Surgeons, Columbia University; the Neurological Institute, the Presbyterian Hospital; and the Medical Department of the Institute for the Crippled and Disabled, New York City

The acute low-back syndrome is based upon a variety of pathological entities. Among these are injuries to the intervertebral disc, actual trauma to the supporting structures, or changes in them, and apophyseal joint disease. Many other etiological factors must certainly exist, and because they exist, the underlying mechanisms in acute low-back disorders, with or without radicular pain, are not always clear.

Fortunately, however, whatever the basic stimulus initiating the acute low-back picture, the reaction pattern is fairly constant. Any local insult to the vertebrae and supporting structures provokes the characteristic response of splinting to prevent further trauma or pain. If there is radicular compression, there may be, in addition, reduction of lordosis and lateral or anterior tilt, both preventing motion and at times relieving the pressure on the compressed root. The splinting is represented clinically by acute muscle spasm, and the tilting by scoliosis. At times, the vicious cycle of pain and muscle spasm may so exaggerate the symptom complex that it is difficult to consider the muscle spasm as purposeful. Indeed, the whole problem may occasionally resolve itself with the simple relief from the muscle spasm.

Treatment of the disorders which make up the "acute low-back" syndrome must obviously be of two types. Specific treatment, when available, is generally radical (operative) in type and its application is contingent upon the results of conservative or non-specific therapy. Non-specific therapy consists in the use of agents for the relief of pain and in attempts at gaining enforced rest for the affected parts.

The striking fact is that almost all regimens depend first upon enforced rest to the affected area, and second upon relief of muscle spasm. The effects of relief from muscle spasm alone make one wonder if it plays a part other than that of secondary protective splinting in the syndrome complex. Several possibilities are conceivable. The splinting may perpetuate the symptoms by fixing the involved parts in an abnormal position, by compromising the blood supply to the area, or by increasing venous congestion. Splinting may also prevent reduction of the root compression by maintaining the vertebral elements in a particular position. It is not inconceivable that maintaining the adjacent vertebrae firmly together increases the bulge of the protuberant disc, the stress upon the limiting ligaments and the apophyseal joints, and consequently the pressure upon the root.

The traditional methods of achieving muscle relaxation are well known and fairly efficient at times. Unfortunately they are not specific and are time-consuming. Since any safe means of obtaining a rapid dissolution of skeletal muscle spasm is of special interest to the orthopaedic and to the neurological surgeon, techniques are legion and represent widely varying approaches. Within recent years the group of pharmacological agents which afford specific muscle relaxation has undergone a great amount of study. Of the group, the drugs with the clinically most useful qualities are the quaternary ammonium salts, exemplified by curare, and the substituted ethers of glycerol, such as myanesin (known in this country as "tolserol" or "lissephen"). The latter is particularly valuable because of the rapidity of its action, its relative safety, and its specificity. In view of its lissive effect, it is natural to attempt to use the drug in the treatment of the low-back syndrome.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N.Y., February 15, 1950.

Myanesin is a synthetic substituted ether of glycerol[1]. It is easily prepared, stable, and almost completely predictable in effect. In high concentrations, it may cause hemoglobinuria and chemical phlebitis. Accordingly, it is given in a 2 per cent. solution in which concentration we have seen no complications[4]. We are concerned with the use of the drug by intravenous injection, where the effect is immediate and predictable. Although it is purported to be effective by mouth, it has not been so in our experience[2,3]; and, at any rate, the levels necessary to obtain rapid relaxation cannot be attained easily by oral administration. It should also be pointed out that myanesin has an analgesic effect similar to that of aspirin, and, in large part, this fact is responsible for its reputed effect when taken by mouth.

Myanesin is a depressant of the motor system by virtue of its damping effect on facilitation mechanisms in the bulbar reticular substance of the brain stem. At somewhat higher concentrations, it will depress segmental motor arcs of the spine; but in general it is more efficient in the multisynaptic tract systems, and least effective in the simpler monosynaptic systems,—such as the deep tendon reflexes. In addition, it has an extremely transient analgesic effect when given intravenously; procaine-like in degree. When given intravenously, the onset of the clinical effect of the drug is abrupt and can be controlled and maintained by the rate of injection.

The sequence of events is of interest: The patient first notices flushing of the circumoral zone, followed by slight fuzziness of vision; then he notes pleasurable relaxation and relief from pain to a dramatic degree. Concomitantly, the observer notes an increase in the amplitude of induced horizontal nystagmus, and at the point of motor relaxation, the onset of vertical nystagmus. At the same point there is striking amelioration of overt motor abnormalities,—such as muscle spasm, tremor, spasticity, rigidity, and involuntary movement of various types.

Since first preparing a 2 per cent. solution of myanesin[4], we have observed its effect upon a series of low-back conditions[2], with the thought in mind of using it to gain rapid and specific muscle relaxation. It was soon apparent that varying responses occurred, each of which, when analyzed in terms of the clinical picture and the eventual outcome, had a concrete physiological basis of some interest.

For the purposes of this discussion, only those patients who were admitted to the Hospital with the diagnosis, physical signs, and severe complaints of disc disease will be considered here. Each patient shortly after admission was given an intravenous injection of approximately 100 cubic centimeters of 2 per cent. solution of myanesin. A careful record of the patient's ability at straight-leg raising was made before the injection was given, together with the data from the usual neurological and orthopaedic examinations. As soon as the level of vertical nystagmus had been reached, after injection was started, the patient's ability at straight-leg raising was again tested, both for actual range and for the point at which pain could be easily elicited. The injection was then continued to 100 cubic centimeters with repeated testing of the range of straight-leg raising. No forced elevation or manipulation was carried out.

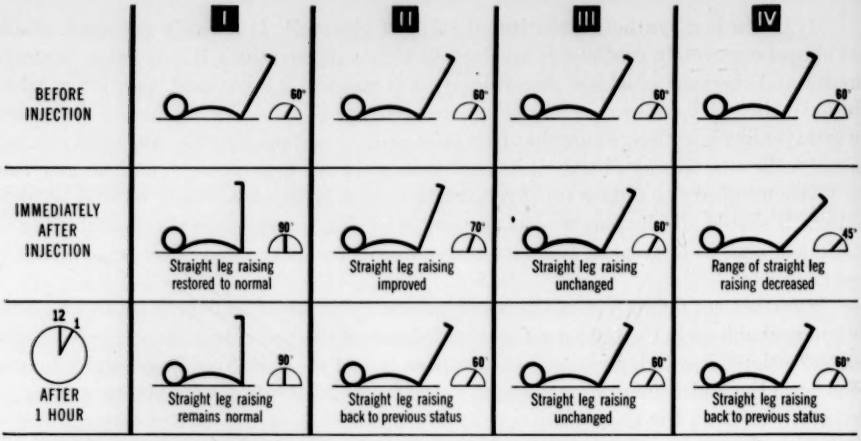
The reactions to the injection of myanesin fell into the following categories (Chart 1):

1. In Group I, there were an abrupt relief from pain and a concomitant striking increase in range of motion, both of which were maintained for varying periods.

2. In Group II, there were also an abrupt relief from pain and a moderate or small increase in the range of motion for varying periods of time, usually of a shorter duration than that in the first group.

3. In Group III, there was an abrupt relief from pain with no increase in the range of straight-leg raising. In this group, however, there was an equally abrupt return of pain on the cessation of injection.

4. In Group IV, there was rapid relief of back pain and "tightness", but with an increase in radicular pain. Interestingly enough, these patients often volunteered the com-



The Four Types of Response

CHART I

ment that they had then to hold their backs stiff to prevent pain. The relief from pain was of short duration and their ability in straight-leg raising never increased, and on occasion, even decreased.

The primary effect of myanesin, as previously stated, is specific potent muscle relaxation, while the secondary effect is analgesic, though it is of short duration. Consequently, the therapeutic results listed above must be considered as the direct results of the reduction of muscle spasm and transient analgesia. The fact that pain did not abate in certain cases is fair evidence that the analgesic effect is not the major factor in the varying clinical results or responses.

The following interpretation is offered for the four types of result:

1. Patients who showed immediate relief of pain and increased motion, with maintenance of effect over relatively long periods, were considered to represent examples of reversible root compression. The dramatic response may have been due to the effect of relieving muscle spasm and its sequelae on the local pathological mechanisms.

2. Those patients who responded obviously to motor relaxation, but not so dramatically as those in Group I, were considered to represent a variation of the first group. Muscle relaxation might have for them a definite therapeutic effect upon the etiological factors responsible for the syndrome, but it is of lesser importance. Conversely, muscle spasm might have a part in perpetuating the syndrome, but not in so great a degree.

3. Patients who had an abrupt relief from pain and a rapid return of pain on the cessation of the injection, but who had no increase in mobility, were felt to represent cases in which root compression was direct, mechanical in type, and not amenable to the effects of muscle relaxation. In other words the part played by muscle contraction in maintaining root compression was minimal.

4. We felt that relief from back pain with increased radicular pain and diminished straight-leg raising indicated marked root compression. In these cases reduction of muscle splinting of purposeful type increased the degree of root compression of mechanical, direct nature. Straight-leg raising was decreased, and voluntary splinting was often necessary to relieve root pain. These apparently represent cases of truly purposeful muscle splinting, with severe root compression slightly alleviated by the splinting and made worse by its dissolution.

The analysis of the case material, presented in terms of test response and follow-up studies, may be summarized as follows:

	Total Cases	Early Operation	Operation at 6 months	Operation at 1 year
Group I	25	0	0	1 (of 8) *
Group II	13	5	3 (of 6) **	0
Groups III and IV	26	26	—	—
Total	64			

* Eight cases have been followed for one year or more.

** Six cases in Group II have been followed for six months or more.

Group I, with eight patients at one year (or more) of follow-up, contains but one operative case. Interestingly enough, this patient was well until one year after the initial hospitalization, when severe pain developed in the opposite extremity, and he was operated upon elsewhere. All patients in Group III and Group IV came to operation within three months. In every instance, the operative report was of inexorable root compression by large herniations or protrusions of the intervertebral disc. Group II is not subject to a clear-cut interpretation or correlation with regard to the end result. It is apparent that, with this type of response, the test lacked real prognostic significance. The mode of treatment in these cases was a direct outcome of the long-term response to conservative or traditional management.

The choice between operative treatment and protracted conservative treatment is often difficult. It is most discouraging to confine a patient to bed for long periods of time and subsequently be forced to abandon such treatment for operation. To many patients the gamble on conservative treatment is economically unfeasible, and they may be forced to demand operative relief for other than sound medical reasons. If one has reliable information upon which to predicate a good result with conservative treatment, it is much easier to be convincing about traction, protracted bed rest, physical therapy, and braces. On the basis of the statistical analysis of results with the myanesin-relaxant test, it seems proper to offer this technique as an addition to the diagnostic and prognostic armamentarium. It should be pointed out that no attempt has been made to correlate the myanesin-relaxant test with long-term outlook; we have been concerned merely with the response to conservative therapy at the time of the acute attack.

In terms of therapy alone, myanesin has an additional usefulness. Although the effects of the drug are evanescent, the muscle relaxation initially gained in minutes may hasten the response to more traditional forms of therapy. Traction may be assisted greatly by preventing the common early "fighting" reaction elicited in muscle and may reach an efficient degree of stretch almost at once, rather than in hours and days. In some cases in Group I, although the effect of the injection is ephemeral, the symptoms and signs abated, and did not return with similar severity. This is likewise seen on occasion after many forms of non-specific therapy of the low back,—such as novocain injection, diathermy, and ethyl-chloride spray. Nevertheless, a drug which can afford safe, repeated specific muscle relaxation should be a most valued tool for the orthopaedic surgeon.

SUMMARY

Myanesin, a specific muscle relaxant of which the chief site of action seems to be the bulbar reticular region, is capable of rapidly dissolving muscle spasm in the "acute disc syndrome". A series of patients with acute low-back and radicular pain were studied before and after the injection of this drug. It was found that pain and limitation of motion of the limb could be altered with gratifying symptomatic relief. In certain instances this response persisted and, when followed by conservative treatment, led to long-term cure. In others there was an abrupt return of pain and limitation of motion as soon as the drug concentration dropped below therapeutic levels. Such patients invariably failed to respond to conservative treatment and eventually came to operation.

The correlation of test response to the drug and prognosis was sufficiently striking in a series of sixty-four patients to warrant discussion as a possible clinical test. In the first group of cases (good response), a high percentage of patients left the hospital symptomatically well after a period of conservative treatment. The group characterized by no response or a rapid return of signs and symptoms immediately after injection quite generally failed to respond to any period of conservative management. Their operative records reveal evidence of root compression of such degree as to make conservative attempts at decompression unfeasible.

REFERENCES

1. Berger, F. M., and Bradley, W.: The Pharmacological Properties of Alpha-Beta-Dihydroxy-Gamma-(2-methylphenoxy) Propane (Myanesin). British J. Pharmacol., **1**: 265–272, 1946.
2. Schlesinger, E. B.: Rationale and Use of Muscle Relaxants in Neuromuscular Disorders. Arch. Phys. Med., **30**: 716–720, 1949.
3. Schlesinger, E. B.; Drew, A. L.; and Wood, B.: Applications of Myanesin in Neurology. Trans. Am. Neurol. Assn., 94–100, 1948.
4. Schlesinger, E. B.; Drew, A. L.; and Wood, B.: Clinical Studies in the Use of Myanesin. Am. J. Med., **4**: 365–372, 1948.

DISCUSSION

Dr. Arthur Steindler, Iowa City, Iowa: The use of myanesin for muscle relaxation in anaesthesia, replacing curare, has called attention to its further use as an antispasmodic in spastic conditions of all kinds. This alpha-beta-dihydroxyl propane (known here as "tolserol"), produces a muscle relaxation which would, in higher degrees, lead to paralysis. In doses of 30 to 50 milligrams per kilogram injected in the rabbit, it caused vasal depression and heart block, the antidote to which was adrenalin.

The superiority of myanesin over intocostrin or tubocurarin, in connection with panthotal in doses of 7 to 28 milligrams per kilogram, and over cyclopropan, which in higher doses has a toxic effect on circulation, is emphasized by Mallinson.[b]

Now, according to a report made by Killian and Maurath[a] on the effect of myanesin on depression of circulation, hemolysis and hemoglobinuria were found in 40 per cent. of the experimental cases, while *in vitro* hemolysis was found up to a dilution of 1.400. This may be mentioned to show that myanesin may not be a harmless drug; in contrast to curare, myanesin acts not only peripherally but it also affects the spine.

The interest of the paper just presented by Dr. Schlesinger and Dr. Stinchfield lies in the use of the drug as an antispasmodic in acute low-back pain, in which they apply it in connection with the conventional treatment by rest and traction. Now, it is well known that the spasm is reflexory and protective, being elicited by the local injury to the soft tissues in the low back. The advantage which seems to lie in this myanesin treatment, as proposed by the authors for this condition, seems to be the promptness of relief of the spasm and the pain associated with it, but I believe that the main value of this method lies in the differential diagnosis.

In the first of the four groups mentioned, relief of the spasm and of the pain was permanent. Obviously, cases in this group were either not cases of true root compression, and the radiation was of reflex character, or the pain was due to a reversible and not to an adherent disc. In both instances, one must assume the existence of a local sacrolumbar strain. I believe the relief position for the sacrolumbar strain—that is, the extensory spasm—was the one which forced the backward herniation of the disc. This is also the principle of the novocain test which, when positive, shows either that the radiation is of reflex character or that the disc is movable and recedes when the position of spasm is relieved by novocain. Quite in keeping with this, is the experience of the authors in Groups III and IV, in which the relief of spasm by myanesin was temporary and sciatic pain promptly returned. These are the cases in which the novocain test surely would have been negative, showing that a type of disc herniation exists, which does not recede on relief of muscle spasm. Therefore, so far as diagnosis and indication are concerned, the myanesin seems to be as useful as the novocain; and, so far as the local relief of spasm, where the spastic low-back pain is concerned, it is probably better.

It is some time since I have heard a paper which, so clearly and lucidly, illustrates the differential point. I wish to thank the authors for the privilege of discussing it.

a. Killian, H., and Maurath, J.: Über Myanesin zur Verbesserung der Entspannung wahrend der Narkose. Deutsche med. Wchnschr., **74**: 946–953, 1949.
b. Mallinson, F. B.: A New Synthetic Curarising Agent in Anaesthesia. Lancet, **1**: 98–100, 1947.

Dr. Alonzo J. Neufeld, Los Angeles, California: I, too, thoroughly enjoyed reading this paper and hearing it. We have had the experience of operating on what we thought was a herniated disc; when we got

(*Continued on page 501*)

THE ROLE OF TENSILE STRESS IN THE MECHANISM OF FEMORAL FRACTURES *

BY F. GAYNOR EVANS, PH.D., HERBERT E. PEDERSEN, M.D., AND H. R. LISSNER, M.S., DETROIT, MICHIGAN

From the Departments of Anatomy and Engineering Mechanics, Wayne University, Detroit

The importance of fractures in medical practice is evident from the mass of literature on the subject. However, most of what has been written deals with the treatment and but little with the mechanism of fractures and the type of forces involved. Homans's is one of the few surgical textbooks that even mentions the problem. This lack of interest in so fundamental a problem is odd, because a clearer understanding of the forces involved in the production of a fracture should enable the surgeon to treat it better and the manufacturer to design more effective protective gear. A knowledge of the type of forces usually involved in the production of various kinds of fractures of the long bones should help the surgeon in the selection of sites for placing pins, wires, or other devices for fixation.

Many years ago, Rauber reported that bone is weaker in resisting tension than compression forces; the importance of this has recently been demonstrated by Gurdjian and Lissner [7, 8, 9, 10] in their studies of skull deformations and fractures. By use of the "stresscoat" technique, these workers have clearly shown that the various types of linear skull fractures arise from failure of the bone under tensile stress. In the present study, an outgrowth of earlier reports on femoral deformations [2, 3, 4, 19], the same will be shown to be true for the common types of femoral fractures.

MATERIALS AND METHODS

Fifty femora from adult, dissecting-room cadavera of known age, sex, race, and cause of death were used. No known pathological specimens were used, and not all bones were loaded to failure.

The fractures were produced by static and dynamic loading of the bones in various orientations. The static loading was done in a hydraulic testing machine (Fig. 1-A) and in a torsion-testing machine with a 10,000 inch-pound capacity. The calibration of both machines indicated an accuracy of better than 0.5 per cent. The dynamic load (Figs. 1-B and 1-C), the energy dynamically applied to the bone, was determined by multiplying the weight of the brass block (7.9 pounds) by the distance, through which it was dropped upon the bone, as measured with an anthropometer. The brass block was released by burning through the supporting cord and was caught by hand on the rebound, so that it struck the bone only once. During a test, all or part of the bone rested upon a steel block weighing 120 pounds. Steel and brass blocks were used because they would absorb very little energy; consequently, most of the energy would be expended in deforming the bone.

In most cases, the bone to be tested was also "stresscoated", so that the tensile deformation pattern produced during the test could be obtained. "Stresscoat" is the trade name for a brittle lacquer which cracks in response to the tensile strain in the material upon which it has been sprayed. The sensitivity of the lacquer to the tensile strain is determined in inches per inch. Thus, a lacquer with a sensitivy of 0.0005 means that, if one inch of the material underlying the lacquer is stretched (tensile strain) as much as 0.0005 inch, the overlying lacquer will crack. The cracks in the lacquer will be transverse to the direction of the tensile strain in the material. The place where they first appear is the area of the highest tensile strain in which failure of the bone will occur under a sufficient load.

* This research was aided by the generosity of Dr. Earl J. Flick and Dr. John R. Flick.

FIG. 1-A

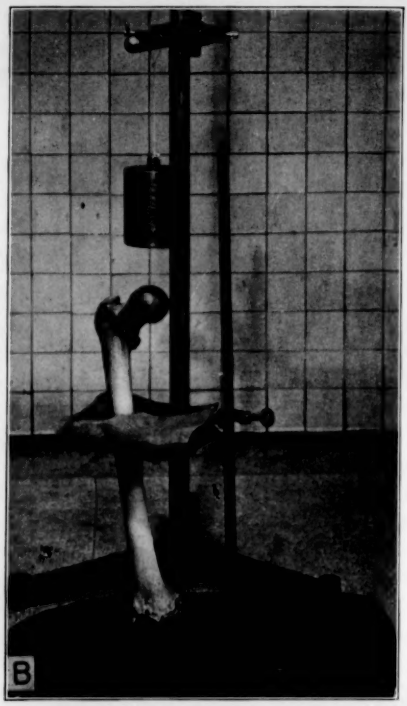


FIG. 1-B

Apparatus used in producing femoral deformations and fractures.

Fig. 1-A: Type of material testing machine used in the static loading tests. (Original by F. Gaynor Evans and H. R. Lissner, *Anat. Rec.*, 100: 159–190, 1948 and reproduced by permission of The Wistar Institute of Anatomy and Biology.)

Fig. 1-B: Apparatus used in the dynamic vertical loading tests. (Original by F. Gaynor Evans, H. R. Lissner, and H. E. Pedersen, *Anat. Rec.*, 101: 225–241, 1948 and reproduced by permission of The Wistar Institute of Anatomy and Biology.)

For photographic purposes, some of the cracks in the deformation patterns were traced with India ink.

"Stresscoat" was developed by deForest and Ellis for industrial use in the testing of aircraft structures and machine parts for points of weakness and failure. The technique was first used in biological research by Gurdjian and Lissner in their studies on skull deformations and fractures. More recently it has been used by Evans and Lissner, and by Evans, Lissner and Pedersen [3, 20] in studying femoral deformations and fractures, and by Spears and Owen in a study of the etiology of trochanteric fractures. The use of the technique is fully described by Evans and Lissner.

In producing the fractures to be described, the authors are well aware that the forces acting upon the femur during the tests were far simpler than those which act upon the femur in the living body. However, the experimental method has the advantage that the orientation of the bone and the type of force, as well as its magnitude, its point of application, and its direction, can be controlled. Consequently, the force can be completely described from the viewpoint of physics. Under these conditions, one can more accurately determine the effect of a known force in producing deformations and fractures of a bone, which is very difficult to do in a living animal because there are so many uncontrollable variables.

The fractures, experimentally produced, were compared with similar clinical types from the records of the Receiving Hospital, Detroit.

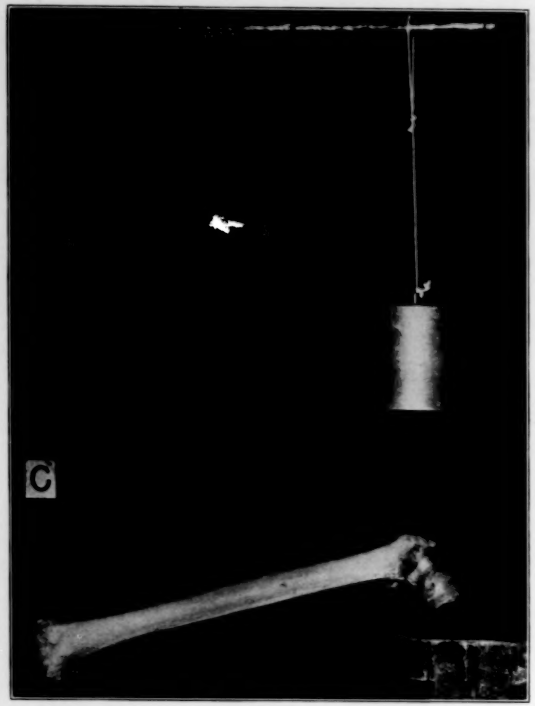


FIG. 1-C

Fig. 1-C: Apparatus used in the dynamic "abduction" loading tests. (Original by H. E. Pedersen, F. Gaynor Evans, and H. R. Lissner, *Anat. Rec.*, 103: 159–185 and reproduced by permission of The Wistar Institute of Anatomy and Biology.)

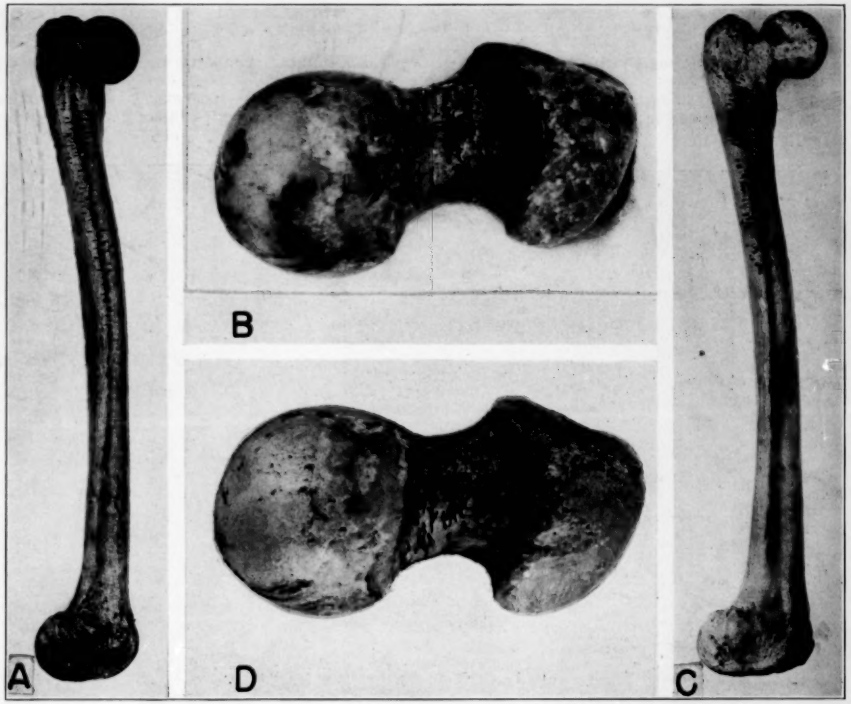


FIG. 2

Fig. 2: Comparison of the deformation patterns produced in the right femur of a white male, sixty years of age, by static and dynamic vertical loading with the infracondylar plane horizontal in position. (Original by F. Gaynor Evans, H. R. Lissner, and H. E. Pedersen, *Anat. Rec.*, 101: 225–241, 1948 and reproduced by permission of The Wistar Institute of Anatomy and Biology.)

A: The "stresscoat" deformation pattern produced in the shaft by a load of 480 pounds statically applied. *B:* Superior view of the neck of the same bone.

C: The "stresscoat" deformation pattern produced in the shaft of the same bone by a load of 15.8 inch-pounds of energy dynamically applied. *D:* Superior view of the neck of the same bone.

FIG. 3

FIG. 4

FIG. 5

Fig. 3, *A:* Superior view of a fracture produced in the neck of a right femur by a load of 1,280 pounds vertically applied to the head. Note that the fracture line, which started on the superior aspect of the neck, is parallel with the cracks in the "stresscoat" lacquer and that it occurred where it was predicted to be from the deformation pattern. *B:* Anterior view of the same fracture. *C:* Close-up view of an unloaded right femur in the testing-machine. Note that the thread, stretching vertically between the shaft and the most medial point on the head, is taut. *D:* The same femur under a load of 650 pounds. Note that the thread is now slack, indicating the bending deformation produced by the load. (Fig. 3, *B*, *C*, and *D:* Originals by F. Gaynor Evans and H. R. Lissner, *Anat. Rec.*, 100: 159–190, 1948 and reproduced by permission of The Wistar Institute of Anatomy and Biology.)

Fig. 4, *A:* A moderately developed "stresscoat" deformation pattern produced in the right femur of a white male, sixty years of age, by 23.7 inch-pounds of energy dynamically applied to the greater trochanter with the bone in the abduction position.

B: A local deformation pattern produced in a left femur in the abduction position by a load of 31.6 inch-pounds of energy.

(Fig. 4, *A* and *B:* Original by H. E. Pedersen, F. Gaynor Evans, and H. R. Lissner, *Anat. Rec.*, 103: 159–185, 1949 and reproduced by permission of The Wistar Institute of Anatomy and Biology.)

C: A subcapital fracture produced in the right femur of a white male, eighty-five years of age, by a load of 560 pounds applied to the greater trochanter with the bone in the abduction position.

D: A clinical, subcapital fracture in the right femur of a white male, sixty-four years of age.

Fig. 5: Intertrochanteric fractures produced by loading the greater trochanter, with the bone in the abduction position.

A: A fracture produced in the right femur of a white male, fifty-five years of age, by a load of 1,290 pounds.

B: A fracture produced in the left femur of the same individual by a load of 1,365 pounds.

C: A fracture produced in the left femur of a white male, eighty-five years of age, by a load of 900 pounds.

D: A clinical intertrochanteric fracture of the right femur of a Negro male, thirty-eight years of age, produced by a fall upon the greater trochanter. Note the similarity to the preceding fracture in the crushing of the greater trochanter.

RESULTS OF THE TESTS

Vertical Loading

Static and dynamic loading tests of the femur in slightly different orientations were made. In one series of tests, the bone was placed vertically, so that the infracondylar plane was horizontal in position, while in a second series the bone was so placed that it made a laterally opening angle of 3 degrees with the horizontal plane. In these positions, according to Walmsley, the bone closely approximated the position of the femur in the living body when the subject was standing with the feet together and apart, respectively. In all the tests, the load was applied vertically to the head of the bone.

The magnitude of the load used in the static and the dynamic loading tests is not directly comparable, since we are dealing with force in the former type of test and with energy in the latter type. However, the location of the "stresscoat" deformation pattern is considered significant; for, in each case it indicates the area of the bone under tensile strain during the test. As seen in Figure 2, the deformation patterns obtained by the two methods of loading were essentially similar. In all cases, the cracks in the lacquer were located on the superior aspect of the neck and the latero-anterior (convex) aspect of the shaft, indicating that those regions of the bone were under tensile strain.

Under static loading, the first cracks were seen to appear on the superior aspect of the neck just lateral to the head and on the shaft a few millimeters distal to the insertion of the glutaeus minimus. This means that those areas were the sites of weakness, where failure (fracture) should occur with a sufficient load. This prediction was completely verified by a fracture (Fig. 3, *A* and *B*) produced by a load of 1,280 pounds statically applied. The fracture line was parallel with the cracks in the "stresscoat" lacquer and started on the superior aspect of the neck just distal to the head. This clearly demonstrates that the fracture arose from the failure of the bone as the result of the tensile stress. Furthermore, the head and neck were seen to be pulled apart as the fracture line spread gradually through the bone with the increasing load. No torsion or twisting of the bone occurred. In the classification of Watson-Jones, this was an example of the common or adduction type of fracture of the femoral neck.

Under static loading, it was also demonstrated that the femur possesses a certain elasticity. At the beginning of each test (Fig. 3, *C*), a thread, extending vertically from the most medial point on the head to the base of the shaft, was taut; but, with an increasing load, it became slack (Fig. 3, *D*) as the bone was bent. However, as soon as the load was removed, the femur returned to its previous condition, and the thread became taut again. Although any body can be deformed when sufficient force is applied, only those which are elastic will return to their former shape.

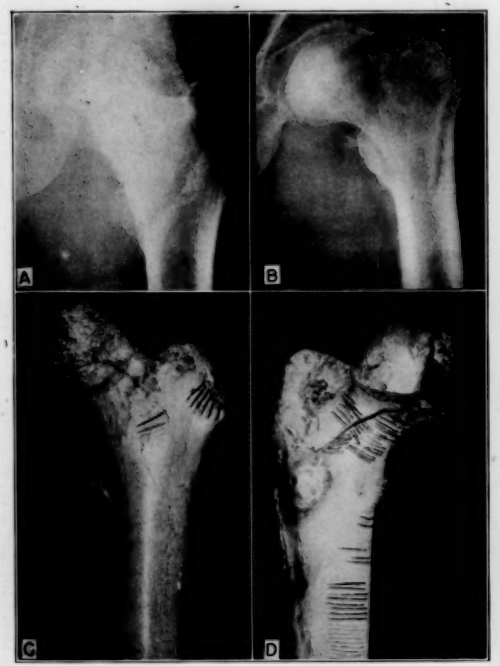


FIG. 6

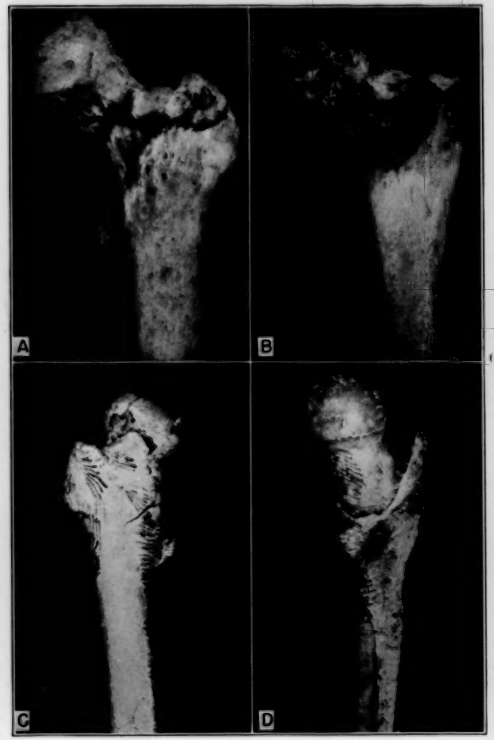


FIG. 7

FIG. 8

Fig. 6, *A:* A clinical intertrochanteric fracture of the left femur of a white female, sixty-two years of age, produced by a fall upon the hip.

B: A similarly produced clinical fracture in the left femur of a white male, seventy-four years of age.

C: An oblique fracture of the neck produced in the left femur of a Negro female, fifty-six years of age, by 355 pounds applied to the greater trochanter with the bone in the abduction position.

D: An oblique fracture of the neck of the left femur of a white male, eighty-one years of age, similarly produced by a load of 805 pounds.

Fig. 7, *A:* A horizontal fracture of the neck of a left femur produced by a load of 400 inch-pounds of energy. The load was applied to the greater trochanter with

the head of the bone elevated 10.6 inches above the floor. (Original by H. E. Pedersen, F. Gaynor Evans, and H. R. Lissner, *Anat. Rec.*, 103: 159–185, 1949 and reproduced by permission of The Wistar Institute of Anatomy and Biology.)

B: A horizontal fracture of the neck of a left femur produced by a load of 308 inch-pounds of energy applied to the greater trochanter with the head of the bone raised 10.6 inches above the floor.

C: Anterior view of a typical abduction fracture produced in the right femur of a Negro female, fifty-six years of age, by a load of 390 pounds applied to the greater trochanter with the bone in the abduction position.

D: Posterior view of the same fracture.

Fig. 8, *A:* A spiral fracture produced in the right femur of a white male, seventy years of age, by 166 inch-pounds of torque.

B: A fracture of the left femur in the same subject (*A*), produced as the result of 448.2 inch-pounds of torque.

C: A spiral fracture produced in the right femur of a white male, fifty-eight years of age, by 498 inch-pounds of torque.

D: Anterior view of the distal third of the preceding bone, showing the "stresscoat" deformation pattern produced during the test.

"Abduction" Loading

In these tests the femur rested on the head and the medial condyle while the load was applied to the greater trochanter. The height of the head above the block was varied in different tests. The static loading tests were made in a testing-machine (Fig. 1-A), and the dynamic loading tests with the apparatus illustrated in Figure 1-C.

The term "abduction" is used to describe the position of the bone because, when the load is applied to the bone, it places the inferior aspect of the neck and the medial aspect of the shaft under such tensile strain as would occur if the thigh were forcibly abducted or as would occur in a fall upon the greater trochanter. Under static loading, the first lacquer cracks appeared on the inferior aspect of the neck and later, with an increasing load, spread down the medial aspect of the shaft (Fig. 4, *A*). The inferior aspect of the neck was thus the area under the greatest tensile strain where failure should occur with a sufficient load.

In a few bones, a well-defined deformation pattern (Fig. 4, *B*) of radiating and concentric cracks was obtained at the site of the impact upon the greater trochanter. Each set of cracks arose from tensile strain in a direction perpendicular to that of the cracks. Thus, both local inbending, indicated by the concentrically arranged cracks, and a general circumferential tension, indicated by the radiating cracks, were produced by the same force.

Of special interest was the obtaining of typical subcapital, intertrochanteric, abduction, horizontal, and oblique fractures of the femoral neck and trochanteric region by static and dynamic loading of the greater trochanter in the abduction position. No torsion or twisting of the bone was involved.

Figure 4, *C* is a subcapital fracture produced in the femur of a white male, eighty-five years of age, by a load of 560 pounds statically applied to the greater trochanter. During the test, the head of the bone rested upon a steel block which raised it five and three-eighths inches above the table of the testing machine. The fracture was seen to start on the inferior aspect of the neck along the epiphyseal line and then to extend gradually through the bone. The fracture, which began in the area of the highest tensile strain, as indicated by the "stresscoat" pattern, was started by the failure of the bone as the result of the tensile stress. For comparison, a clinical fracture of a similar type in the femur of a white male, sixty-four years of age, is illustrated in Figure 4, *D*.

Some of the intertrochanteric fractures obtained in the tests are illustrated in Figure 5. The fracture in Figure 5, *A* was produced in the femur of a white male, fifty-five years of age, by a load of 1,290 pounds statically applied to the greater trochanter. During the test, the bone rested on the head and the medial condyle, which were flat on the table of the testing machine. The head of the other bone of the pair (Fig. 5, *B*) was elevated three inches during the test and did not fail until a load of 1,365 pounds had been applied. In the

femur of a white male, eighty-five years of age (Fig. 5, *C*), with the head raised three inches from the block during the test, there was a preliminary crushing of the greater trochanter before failure under a load of 900 pounds. In all three bones, the fracture was seen to start on the inferior aspect of the neck and to spread gradually through the bone. Here again, comparison with the "stresscoat" deformation pattern shows that the fracture arose from the failure of the bone under tensile stress. In one bone, the greater trochanter (Fig. 5, *C*) also showed a pattern of local tensile deformation, produced by the inbending of the bone under the load. The crushing of the greater trochanter in this bone is similar to that which occurred in a Negro male, thirty-eight years of age (Fig. 5, *D*), as the result of striking his hip on the edge of the bath tub when he fell. Clinical examples of intertrochanteric fractures, as the result of a fall upon the hip, in a white female, sixty-two years of age, and a white male, seventy-four years of age, are illustrated in Figure 6, *A* and *B*.

Some oblique fractures of the neck of the femur were also obtained: In the femur of a Negro female fifty-six years of age, which failed under a load of 355 pounds (Fig. 6, *C*), the fracture began on the inferior aspect of the neck in the region of the epiphyseal line and gradually extended to the middle of the intertrochanteric line. During the test, the head was elevated five and three-eighths inches. In the femur of a white male, eighty-one years of age (Fig. 6, *D*), which failed under a load of 805 pounds, the fracture began in a place similar to that in the preceding case and extended toward the greater trochanter, which had undergone some crushing before the actual fracture. The head of the femur was raised three inches during the test. In both bones, the fracture line was parallel with the "stresscoat" cracks on the inferior aspect of the neck in the region which, as indicated by the deformation pattern, was the area of the highest tensile strain. These examples indicate that in each case the fracture arose from the failure of the bone under tensile strain. The greater trochanter of both bones showed a local deformation pattern produced by the inbending of the bone at the point of the load application.

Similar, but more horizontal, fractures of the femoral neck were produced also by the dynamic loading of the greater trochanter. The bones used were from the student-loan collection, and no data about them were available. The fracture in bone *A* (Fig. 7, *A*) was produced by a load of 400 inch-pounds of energy and that in bone *B* (Fig. 7, *B*) by 308 inch-pounds. At the time of the test, the head of each bone rested on steel blocks which raised each 10.6 inches above the concrete floor.

Although the actual fracture of these bones happened too quickly to be observed, previous experiences from "stresscoat" tests under static loading convince us that the fracture probably began on the inferior aspect of the neck as the result of failure under the tensile strain.

The most interesting fracture (Fig. 7, *C* and *D*) occurred in the femur of a Negro female, fifty-six years of age, under a load of 390 pounds, applied statically to the greater trochanter. During the test, the head of the bone rested on a steel block, which raised it three inches above the level of the table of the testing machine. The fracture was unique in that it started on the superior aspect of the neck at its junction with the greater trochanter. From there it extended gradually along the posterior margin of the intertrochanteric line to the lesser trochanter. During the test, the angle between the neck and the shaft axes gradually opened out, until, at the end of the test, the two were in almost a straight line, and the head and neck were firmly impacted with the shaft. This was the only example of the clinically rare abduction fracture. The classification of fractures into the abduction and the adduction type, which was introduced into clinical work by Watson-Jones (preceded by the work of Pauwels, discussed by Karfoil), is based upon the obliquity of the fracture line.

Torsion Loading

Spiral fractures of the shaft were produced by placing the bone in a torsion machine;

FIG. 9

A: Posterolateral view of the "stresscoat" deformation pattern produced in a left femur by 514.6 inch-pounds of torque.
B: Posteromedial view of the same bone.
C: Anterior view of the right femur of a white male, sixty years of age, which failed under 282.2 inch-pounds of torque.
D: Posterior view of the same bone. Note that the fracture line closely parallels the cracks in the deformation pattern.

the accuracy of the calibration of this machine varied approximately 0.5 per cent. Specifically designed clamps for grasping the head and the greater trochanter proximally, and the condyles distally, were made to hold the bone in the machine. The bone was placed in the machine so that the axis of rotation passed through the center of the shaft at the intercondylar and the greater trochanteric levels. During each test, the distal end of the bone was fixed, and a torque, medially directed, was applied to the greater trochanter. This was intended to simulate the lateral rotation of the thigh with the proximal end of the bone fixed or the medial rotation of the proximal end with the distal end fixed. Because of the design of the clamps, the head, neck, and greater trochanter rotated as a unit as they do in the living body. The twisting moment applied to the bone was indicated in units of 8.3 inch-pounds of torque by the gauge on the torsion machine. One inch-pound of torque is the twisting moment produced by one pound of force acting at a distance of one inch from the center of rotation.

The bones tested were also "stresscoated" in order to obtain the tensile deformation pattern produced by the test. The torque was gradually increased until cracks were seen in the lacquer; an attempt was then made to obtain minimal, moderate, and extensive deformation patterns. However, the cracks were often difficult to see, although frequently they formed more extensive patterns than were anticipated. In some cases, the bone failed before the presence of the cracks was noted. During a test, the first cracks appeared on the neck and then cracks appeared on the shaft just distal to the greater trochanter. The former cracks were transverse to the long axis of the neck, while the latter were at a 45-degree angle to the long axis of the shaft. The deformation pattern as a whole took a spiral course around the shaft at a 45-degree angle to its long axis (Fig. 9, *A* and *B*).

The clamps holding the head and the greater trochanter acted in such a way that a force was applied to the anterior aspect of the head and to the posterior aspect of the greater trochanter. These two forces constituted a couple which rotated the mass (head, neck, and greater trochanter) as a unit, and set up tensile strain, as indicated by the "stresscoat" cracks, in the neck. The cracks themselves arose from the bending action in the neck. Under the conditions of the test, failure should have started in the neck, since the first cracks appeared there; but the deformation pattern was small and, because of the clamp, could not go beyond the elastic limit of the bone. During a test, the torque, as indicated by the 45-degree angle of the cracks, occurred in the shaft and not in the neck.

That the spiral fracture of the shaft is simply another example of the failure of the bone as the result of the tensile stress, and thus not essentially different from a fracture produced by bending failure of the bone was clearly demonstrated by the "stresscoat" pattern. This was clearly illustrated in the femur (Fig. 9, *C* and *D*) of a white male, sixty years of age, which failed under a load of 282.2-inch pounds of torque. The fracture line was almost exactly parallel with the cracks in the "stresscoat" lacquer and followed the deformation pattern in its spiral course around the shaft. Similar fractures were produced in the femora of a white male, seventy years of age. The right bone (Fig. 8, *A*) failed under a torque of 166 inch-pounds and the left (Fig. 8, *B*) at 448.2 inch-pounds, although cracks appeared on the neck with the application of 166 inch-pounds. Both fractures took a spiral course around the shaft, and in the right bone the fracture line was closely parallel with the "stresscoat" cracks. The femur of a white male, fifty-eight years of age, did not fail until a torque of 498 inch-pounds had been applied (Fig. 8, *C* and *D*). This bone also showed a rather unusual deformation pattern on the distal half of the shaft. Two sets of cracks, placed at approximately right angles to each other, were present. Those on the anterolateral aspect of the shaft were parallel with the direction of the fracture line and arose from the initial tensile strain produced in the bone by the torque. The set of cracks on the anteromedial aspect of the shaft were produced by the instantaneous unloading of the bone because of the fracture. This phenomenon occurs because of the plastic creep in the "stresscoat" lacquer under slowly applied loads.

That these fractures were not unique types is shown by comparison with a clinical example of a spiral fracture (Fig. 10, *A*). The angle of the fracture line, at approximately 45 degrees to the long axis of the shaft, is typical of torsion failure.

Transverse Loading

In this series of tests, the bone was so laid on the table of the testing machine that it rested upon the posterior aspect of its head and condyles. The load was statically applied to the mid-point of the anterior aspect of the shaft in a direction transverse to its long axis. In order to concentrate the force at the target site, the load was applied to a circular steel rod, 1.5 inches in diameter, which was placed transversely across the bone.

In every test, the fracture was seen to start on the posterior (tension) aspect of the shaft opposite the point of application of the force. The "stresscoat" deformation patterns produced in the tests clearly indicated a failure of the bone under tensile strain.

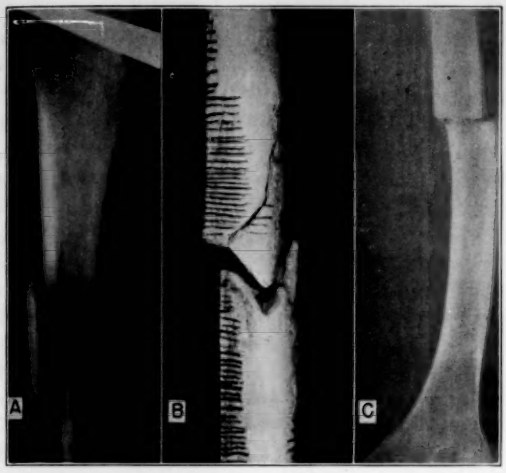


FIG. 10

FIG. 11

Fig. 10, *A:* A clinical spiral fracture of the right femur of a Negro male, forty-nine years of age, resulting from a fall while on crutches.
B: A transverse fracture produced in the shaft of the right femur of a white male, seventy-nine years of age, by a cross-bending load of 360 pounds.
C: A transverse, slightly comminuted fracture of the left femur of a white female, sixty-six years of age, resulting from a fall on the ice.

Fig. 11: A clinical transverse fracture of the neck of the right femur of a white male, forty-three years of age, arising from a fall upon the greater trochanter.

Figure 10, *B* is a photograph of a fracture produced in the femur of a white male, seventy-nine years of age, by a load of 360 pounds. The fracture began on the posterior aspect of the shaft, parallel with the "stresscoat" cracks, and spread gradually through the bone. A typical bending failure in a clinical case is illustrated in Figure 10, *C*.

DISCUSSION

The authors are quite cognizant of the fact that the forces acting upon the living femur, especially as the result of muscular and ligamentous attachment, are far more complex than those involved in the present tests. However, the tests have the greater advantage of enabling one to observe and to study the behavior of a given bone under certain controlled conditions. Thus, the effects produced by a force of known magnitude, point of application, and direction can be studied quite accurately.

From a clinical viewpoint, the most interesting result of the tests was the variety of fractures produced by the loading of the greater trochanter. All of the common clinical types, except the spiral fracture of the shaft of the femur, were obtained without any torsion or twisting. *Apropos* of the latter fact, a transverse fracture of the femoral neck (Fig. 11) in a surgeon friend of the authors' is especially significant, as it was produced when the patient fell from a ladder and landed squarely upon his greater trochanter. There was no torsion or twisting force involved, and the fracturing force was applied to the greater trochanter in a manner quite similar to that used in the dynamic abduction loading tests.

Transverse fractures of the femoral neck have often been considered to be the result of torsional forces acting upon the neck. The usual course of events is supposed to be essentially as follows: The patient twists the leg, as the result of tripping over something, which causes the neck of the femur to break; and then the patient falls as the result of the fracture. Such, however, does not seem to be the usual cause; and McElvenny, who cites several cases, is of the opinion that quite a few of the typical fractures of the femoral neck

occurring in the absence of trauma are pathological in nature. A careful questioning of hospital patients with transverse fractures of the femoral neck did not produce the supposed history. Furthermore, the abduction loading tests, as well as the clinical case illustrated in Figure 11, showed that no torsional force was involved in the fracture mechanism.

Transverse fractures of the femoral neck probably never arise as the result of torsion in the neck of the bone. Torsion, as distinct from rotation, produces an angular change in any two points, with respect to each other, on opposite ends of a bone. During this process one end of the bone must be relatively fixed, while the opposite end is being twisted about the long axis of the bone. Thus torsion of the neck of the femur cannot normally occur in the living body, as there is no mechanism for fixing one end—that is, the head of the femur or the greater trochanter—while the opposite end is being twisted about the long axis of the neck. Both the head and the neck of the femur are entirely intracapsular, and the only structure attached to either is the ligamentum teres. However, since this is often reduced to a few strands of tissue and since its centrally located attachment to the head of the femur means that it lies in the axis about which the head rotates in movements of the hip joint, it could only help to hold the head of the femur in the acetabulum.

The muscles attached to the greater trochanter act at the end of a lever arm, consisting of the femoral head and neck which must move together as a unit. One of the most important functions of muscles, as shown by Elftman, Fenn, and others, is to prevent movements from proceeding so far in one direction that the joint is dislocated. Thus, the chances of the femoral head being so fixed against the acetabulum that the muscles attached to the greater trochanter could produce a torsional strain in the neck of the bone are very remote.

In the torsion-loading tests, one end of the bone was fixed, while the torque or twisting force was applied to the opposite end. As previously mentioned, the torsion occurred in the shaft of the bone and not in the neck. That the spiral course of the fracture line around the shaft was at a 45-degree angle to its long axis and was parallel with the "stresscoat" deformation pattern indicates that these fractures are just another example of the failure of the bone as the result of the tensile stress.

Another point of some clinical interest is the rarity of injury to the greater trochanter during the tests, although the force applied to it was often sufficient to fracture the bone. It would seem to indicate that cancellous bone is an energy-absorbing material, which is best developed in those regions of the bone where the compacta is thin. Absence of injury to the greater trochanter is commonly seen in clinical fractures of the neck and the trochanter. The probable explanation for this fact is the excellent energy-absorbing qualities of the soft tissues (skin, tela subcutanea, aponeurosis of the glutaeus maximus, and bursa) overlying the greater trochanter. Gurdjian, Webster, and Lissner[10], found that a relatively thin layer of soft tissue (the scalp) is an excellent energy-absorbing material and that the amount of energy required to fracture the intact skull was about 600 inch-pounds on the average, while as little as 40 inch-pounds of energy would fracture the cleaned skull. The thickness of the scalp in their specimens varied from 1.5 to 8 millimeters. The presence of the supratrochanteric bursa is an additional protection, since the fluid within it can withstand a considerable amount of pressure. Jones found that the film of synovial fluid, which is similar to the fluid in a bursa, in a proximal interphalangeal joint of a human finger withstood a load amounting to a surface pressure of 900 pounds per square inch. The composition of the greater trochanter itself, a shell of compact bone filled with cancellous bone, is also a good energy-absorbing material.

The gross anatomical factors influencing the strength of the femur and the load it can support in the erect posture are:

The general size of the bone;
The shape and diameter of the neck and the shaft;
The curvature of the shaft;

The degree of forward torsion of the head and the neck upon the shaft;
The thickness of the compacta;
The distribution and arrangement of the cancellous bone;
The angles that the neck, shaft, and load axes make with one another.

Age, sex, and perhaps race also have their influence.

The mechanical factors involved in the same problem are the magnitude, the point of application, and the direction of the forces acting upon the bone. These factors, plus the orientation of the bone, were the controlled variables during a test.

In the erect position of the body, the femur may be compared with an eccentrically loaded column. Such a column is subjected to a bending action superimposed upon a compression action. This action produces tensile strain in the convex side of the bent column; and an additional compression in the concave side. In a vertically loaded femur, the superior aspect of the neck and the anterolateral (convex) aspect of the shaft would be subject to tensile strain as was clearly proved by the "stresscoat" deformation pattern (Fig. 2) produced by vertical loading.

The magnitude of the tensile strain, developed in the femur under vertical loading, is dependent upon the diameter of the bone, the thickness of the compacta, the size of the load, and the perpendicular distance of the load axis from the center of the bone. The latter factor is a function of the angles the neck, the shaft, and the load axes make with one another. The forces acting upon the neck of the femur, as the result of the body weight, are analyzed mechanically in Figure 12. In Figure 12, *a* we assume that the load axis is parallel with the anatomical (shaft) axis; in Figure 12, *b* let us assume that a force, P_1, acting along the load axis, is parallel with the anatomical axis.

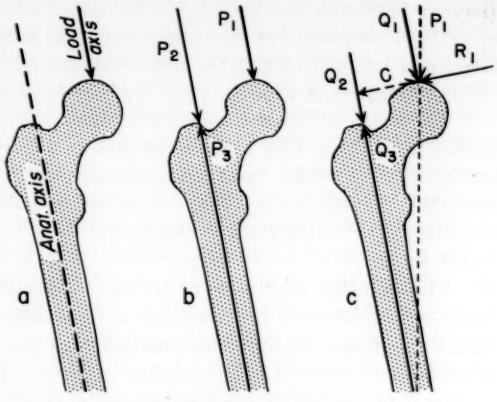


FIG. 12

Forces acting upon the neck of the femur in the erect posture.

For the purposes of analysis, we can introduce, without changing the mechanical conditions, two equal and opposite forces, P_2 and P_3, which act along the anatomical axis parallel with the load axis. The force P_2 would produce compression of the shaft, while the force P_3 is equal, opposite, and parallel to the force P_1. These two forces, acting as a couple, tend to bend the head and neck of the femur downward. However, the load axis is not actually parallel with the anatomical axis, and in Figure 12, *c* is an analysis of the conditions as they would exist in a normal femur. Here the load axis makes an angle with the anatomical axis; and the force P_1, acting along the load axis, has been broken down into its components, Q_1 and R_1. Again, for analytical purposes, we can introduce, without changing the mechanical conditions, the forces Q_2 and Q_3, which are equal and opposite and act along the anatomical axis parallel with the force Q_1. The force Q_2 would cause compression of the shaft, while the forces Q_1 and Q_3 constitute a couple tending to bend the head and neck downward. This tendency is resisted by the force R_1, which is one of the constituents of a couple effecting an upward rotation of the head and neck. The magnitude of the tendency for the applied load to produce a downward bending of the head and neck is directly proportional to the perpendicular distance (C) of the point of application of the force from the anatomical axis. This distance is a function of the size of the angle between the axes of the neck and of the shaft. The magnitude of the tensile strain at any given point on the bone is approximately proportional to the perpendicular distance of that point from the load axis.

The angles which the neck, shaft, and vertical axes make with one another influence the weight-supporting capacity of the femur in another way. The larger the angle between the neck and the shaft axes and the smaller the one between the shaft and the vertical axes, the greater the load the femur can support, because the load and the shaft (anatomical) axes are closer together. If the former angle were 180 degrees and the latter 0 degree, the load and shaft axes would coincide, and the femur would then be a concentrically loaded column, capable of supporting considerably more weight.

It should also be remembered that the femur is hollow. This is important because, according to the principles of physics, a tubular structure, in proportion to the amount of material used, is stronger in resisting bending action than is a solid one. As previously mentioned, this is the type of action to which the femur is most commonly subjected in the living body. However, since the shaft of the femur is not of uniform diameter throughout, various regions are strengthened by a thickening of the shaft.

According to an abstract in a recent number of *Excerpta Medica*, Pauwels has also recognized the importance of bending forces acting upon long bones, as well as the role of the mono-articular and the biarticular muscles in relieving them.

The arrangement of the trabeculae in the femur is also considered to be related to the stress and strains to which the bone is subjected in the living body, and it was so used in the development of Wolff's law of bone architecture.

The speed with which a load is applied is important, since a greater load can be supported if it is gradually applied. As seen in Figure 2, a small load suddenly applied may produce deformations nearly as extensive as those resulting from much greater loads gradually applied. It is, therefore, of considerable interest that, according to Elftman, the muscles of the inferior extremity act so that the weight of the body is *gradually* applied to the femur.

The question may arise as to how closely deformation patterns obtained from dry bones resemble those in living bones. The difficulties of performing "stresscoat" tests on a living femur are obvious, but Gurdjian and Lissner [7], working with the skull, have provided an answer to the question. They conducted three series of "stresscoat" tests on the skulls of six dogs. The first series of tests were on the skulls of living anaesthetized dogs, the second series on the skull of a dead dog with the brain *in situ*, and the third series on the dry skulls of the same animals. A similar series of experiments were also performed upon a rhesus monkey. They found that the deformation patterns obtained, whatever the experimental conditions, were essentially the same. The only difference noted was that the deformation patterns in the living animal were slightly more extensive than those in the dry skull.

The most important result of the tests was the clear demonstration of the influence of tensile stress in the mechanism of fractures. With the exception of the single example of the true abduction fracture, all the fractures experimentally produced arose from the failure of the bone as the result of the tensile stress. This was definitely proved by the close correlation between the point of origin and the course of the fracture line and the "stresscoat" deformation pattern. This is especially significant with respect to the spiral or torsion fractures of the shaft, which have sometimes been considered to be the result of failure under shear. The spiral course of the fracture line around the shaft, in close correspondence with the torsion deformation patterns, is a typical tension failure. According to mechanical principles, the fracture line would have to be straight across the shaft at a right angle to its longitudinal axis if it arose from shearing-stress failure.

Transverse fractures of the femoral neck have also been thought to be shear failures. However, as demonstrated by the vertical-loading tests and the abduction loading tests, transverse fractures are also failures produced by tensile stress. However, as emphasized by Pauwels (discussed by Karfoil), shear may be a serious force with which to contend in the treatment of femoral-neck fractures. Thus, the more vertical the fracture line, the

greater the tendency for the fragments to shear. However, if the fracture line is more nearly horizontal in position, as in the typical abduction fracture, the fragments tend to become impacted, and union would occur without resort to pinning or wiring. Shear, however, does not seem to be involved in the origin of the fracture.

Messerer's studies on the strength of intact bones also demonstrated failure of the bone under tensile strain. He stated that the neck fractures obtained by vertical loading ran from above downward, while those resulting from cross-bending loading of the shaft always started on the convex side. Thus, in each case, the fracture began on the side of the bone under tensile strain during the test. His illustrations of fractures obtained by these methods of loading as well as by torsion, show conditions very similar to our own.

The role of tension in the fracture mechanism of long bones was also pointed out by Rixford on the basis of his clinical experience. However, this information is not included in most textbooks of surgery or even in those on fractures.

Recently, in an experimental study on the etiology of trochanteric fractures, Spears and Owen used the "stresscoat" technique to a slight extent. However, in spite of the evidence of their "stresscoat" patterns, they talk of their trochanteric fractures as resulting from a failure of the femur under shear or compression. The fact that both ends of the bone were quite firmly fixed during their tests and that they applied the force to the lateral aspect of the greater trochanter means that the entire trochanteric region of the bone was subjected to a bending action as the result of the impact. Consequently, as illustrated by their photograph of the pattern of the "stresscoat" deformation, the medial aspect of the trochanteric region was under tensile strain. The fractures they discuss very probably resulted from a failure of the bone under tensile strain as was the case in our tests. The same is probably also true of their deformations at the site of impact,—that is, as failure, under the tensile strain, arising from the inbending of the bone.

As previously mentioned, our single example of an abduction fracture, in which the head and neck were firmly impacted with the shaft, was unique in having the first failure occur on the superior aspect of the neck at its junction with the greater trochanter. This bone, one of three, had an angle of 134 degrees between the axis of the shaft and the neck, the highest value in our series. Consequently, the shaft and the neck were not in a good mechanical position to resist being forced apart by a load applied to the greater trochanter. During the test, the angle between the shaft and the neck gradually opened out with the increased load, until, at the end of the test, the shaft and the neck were in almost a straight line. This upward rotation of the head and neck during the test forced the superior aspect of the neck into the greater trochanter. Since the force was acting along the long axis of the superior aspect of the neck and at a tangent to the greater trochanter, the latter gave way first. Continued upward rotation of the neck forced it more deeply into the substance of the greater trochanter, and, at the same time, it set up tensile strain on the inferior aspect of the neck. Finally, this region failed under the strain, and a linear fracture spread through the bone to the area of the first failure, where the superior aspect of the neck was impacted with the greater trochanter. Comparison with the "stresscoat" pattern on the inferior aspect of the neck showed that the linear fracture originated from failure of the bone under tensile strain. "Stresscoat" cracks, arising from the tensile strain caused by the inbending of the bone as the neck was being forced into it, were also present on different aspects of the greater trochanter.

The importance of tensile strains and stresses in the mechanism of femoral fractures was also recognized by Küntscher. He coated bones with melted colophonium, which cracked in response to the tensile strain, and obtained tensile-deformation patterns resembling those we secured with similar types of loading. He likewise found that the fracture lines corresponded to the areas of the highest tensile stress. Furthermore, in his static loading tests, the gradual spread of the fracture coincided with the cracks in the colophonium. He obtained spiral tensile-strain patterns by torsion loading and noted the

role of tension forces in torsion fractures. However, as shown by Evans, Lissner, and Pedersen, his method is neither so accurate nor so satisfactory for this type of study as is the "stresscoat" technique.

Matti, in contrast to the majority of textbooks on fractures in the English language, has also emphasized the importance of the various types of forces involved in the mechanism of fractures and devotes an entire chapter of thirty-nine pages to a discussion of them.

SUMMARY

1. Static and dynamic loading tests were made on fifty femora from dissecting-room, adult cadavera of known sex, age, and race. The cause of death was also known, and no grossly pathological bones were used. All bones were not loaded to failure.

2. Most of the bones were "stresscoated" so that the tensile deformation pattern produced during the tests was obtained.

3. In each test the magnitude, point of application, direction, and type of force, as well as the orientation of the bone, were the controlled variables. These factors, however, were not uniform in all tests.

4. Vertical transverse fractures of the femoral neck were produced by static vertical loading of the femoral head. No torsional force was involved.

5. Static vertical loading of the femur clearly demonstrated its behavior as an elastic body.

6. Subcapital, intertrochanteric, abduction, horizontal, and oblique fractures of the neck were obtained by static and dynamic loading of the greater trochanter, with the bone in slightly different positions. No torsion was involved in the fracture mechanism.

7. Spiral fractures of the shaft were produced by static torsion loading.

8. Transverse fractures of the shaft were produced by cross-bending loads.

9. The "stresscoat" deformation patterns obtained in the fractured bones clearly demonstrated that, with the possible exception of the abduction type, each of the various kinds of fractures arose from the failure of the bone as the result of the tensile strain.

10. Contrary to a rather general belief, transverse fractures of the femoral neck are not produced by torsional forces. There is no mechanism in the living body that can produce torsional strain in the femoral neck.

11. Shearing force is also not involved in the fracture mechanism although, depending upon the obliquity of the fracture line, it can be a serious factor in the treatment of such fractures.

12. Spiral fractures of the shaft are merely other examples of the failure of the bone as the result of the tensile strain. They do not arise from shearing stress.

REFERENCES

1. Elftman, Herbert: Forces and Energy Changes in the Leg During Walking. Am. J. Physiol., **125**: 339–356, 1939.
2. Evans, F. G., and Lissner, H. R.: "Stresscoat" Deformation Studies of the Femur under Static Vertical Loading. Anat. Rec., **100**: 159–190, 1948.
3. Evans, F. G.; Lissner, H. R.; and Pedersen, H. E.: Deformation Studies of the Femur under Dynamic Vertical Loading. Anat. Rec., **101**: 225–241, 1948.
4. Evans, F. G.: Studies of Femoral Deformation. Stanford Med. Bull., **6**: 374–381, 1948.
5. Fenn, W. O.: The Mechanics of Muscular Contraction in Man. J. Applied Physics, **9**: 165–177, 1938.
6. de Forest, A. V., and Ellis, Greer: Brittle Lacquer as an Aid to Stress Analysis. J. Aeronaut. Sciences, **7**: 205–208, 1940.
7. Gurdjian, E. S., and Lissner, H. R.: Deformation of the Skull in Head Injury. A Study with the "Stresscoat" Technique. Surg., Gynec., and Obstet., **81**: 679–687, 1945.
8. Gurdjian, E. S., and Lissner, H. R.: Deformations of the Skull in Head Injury Studied by the "Stresscoat" Technique, Quantitative Determinations. Surg., Gynec., and Obstet., **83**: 219–233, 1946.
9. Gurdjian, E. S.; Lissner, H. R.; and Webster, J. E.: The Mechanism of Production of Linear Skull Fracture. Further Studies on Deformation of the Skull by the "Stresscoat" Technique. Surg., Gynec., and Obstet., **85**: 195–210, 1947.

10. Gurdjian, E. S.; Webster, J. E.; and Lissner, H. R.: Studies on Skull Fracture with Particular Reference to Engineering Factors. Am. J. Surg., **78**: 736–742, 1949.
11. Homans, J.: A Textbook of Surgery, Ed. 3. Springfield, Illinois, Charles C. Thomas, 1935.
12. Jones, E. S.: Joint Lubrication. Lancet, **1**: 1043–1044, 1936.
13. Karfoil, G. J.: Pauwels' Reclination, Physiological Reconstruction for Non-United Fracture of the Neck of the Femur. Surg., Gynec., and Obstet., **68**:648–657, 1939.
14. Küntscher, Gerhard: Die Bedeutung der Darstellung des Kraftflusses im Knochen für die Chirurgie. Arch. f. Klin. Chir., **182**: 489–551, 1935.
15. Matti, H.: Die Knochenbrüche und ihre Behandlung. Berlin, Julius Springer, 1918.
16. McElvenny, R. T.: Roentgenographic Interpretation of What Constitutes Adequate Reduction of Femoral Neck Fractures. Surg., Gynec., and Obstet., **80**: 97–106, 1945.
17. Messerer, O. Über Elasticität und Festigkeit der menschlichen Knochen. Stuttgart, Cotta, 1880.
18. Pauwels, F.: Über die Bedeutung der Bänder und Muskeln für mechanische Beanspruchung der Röhrenknochen. Schweiz. med. Wchnschr., Basle, **79**: 461, 1949. (Abstracted in Excerpta Medica, Sect. I, **4**: 11–12, 1950.)
19. Pedersen, H. E.; Evans, F. G.; and Lissner, H. R.: Deformation Studies of the Femur under Various Loadings and Orientations. Anat. Rec., **103**: 159–185, 1949.
20. Rauber, A. A.: Elasticität und Festigkeit der Knochen. Leipzig, Engelmann, 1876.
21. Rixford, E.: The Mechanism of Fractures. J. Am. Med. Assn., **61**: 916–920, 1913.
22. Spears, G. N., and Owen, J. T.: The Etiology of Trochanteric Fractures of the Femur. J. Bone and Joint Surg., **31-A**: 548–552, July 1949.
23. Walmsley, T.: The Vertical Axes of the Femur and their Relations. A Contribution to the Study of the Erect Posture. J. Anat., **67**: 284–300, 1932.
24. Watson-Jones, R.: Fractures and Joint Injuries, Ed. 3. Baltimore, Williams and Wilkins Co., 1943.

DISCUSSION

The Use of Muscle Relaxants

(*Continued from page 484*)

in, we found what I choose to call a wet hole instead of a dry one. In other words, when we had detached the ligamentum flavum and folded the dura aside, we found a large, thickened, engorged, inflamed nerve root. We were unable to find a satisfactory explanation for what we did during the surgical procedure. This particular situation, I cannot help but feel, is similar to that which we frequently find in shoulder lesions,—degenerative lesions of the shoulder cuff.

It seems to me that the high point of this paper was the analysis of Groups III and IV. If a test does tell us nothing more than when to operate and when not to, it will be one of the biggest contributions we have had for a long time. There are a few questions, however, which come to mind.

The first is raised by the fact that there is a great deal of difference in reaction to the speed of injection of drugs. The authors alluded to the biological responses which these patients had during the injection, but they did not tell us how fast they gave the injection or what they considered the ideal rate of injection.

The second is raised by the fact that the same dosage of the drug was given to everyone, whether an old lady, or a youngster with spastic paralysis.

The third point that I would like to question is the possibility of drug allergies. Those of us who have used myanesin orally for some time have had no little difficulty with some of our patients; thus, if the drug produces an allergy when given by mouth, it is not impossible that it may also do so when it is given intravenously.

I wish again to thank the authors for bringing to us a very clear and concise analysis of their topic.

Dr. Schlesinger (closing): It is interesting to note, so far as the harmlessness of the 2 per cent. solution is concerned, that the British apparently use a 10 per cent. solution of myanesin in propylene glycol and alcohol (a horrible potion!). That they like small ampoules seems to be the reason this concentration was chosen. I think that this combination of pharmacological ingredients is responsible for the high incidence of phlebitis, and the bad reputation which the drug has achieved. We, I believe, were the first to use a 2 per cent. solution of myanesin, and with this preparation we have seen nothing but a transient chemical phlebitis. This occurred in cases in which we traumatized the vein by prolonged or repeated injections as in the treatment of tetanus.

I should like to emphasize that we do not use the myanesin test in all cases, but rather we use it where there is a question as to the necessity of operation. If a patient has marked paresis or any neurological disturbance of significance, we do not subject him to this test. Interestingly enough, we have done myelograms on many of the patients who have had the test, and some of the most brilliant responses were in people who had had unequivocal myelographic defects. This, of course, merely means that there is sufficient room for the nerve root in spite of the protrusion. In other words, the test cannot be interpreted as meaning that no disc is involved.

(*Continued on page 504*)

RECURRENT SUBLUXATION OF THE ANKLE

With Special Reference to Peroneal-Nerve Block as a Diagnostic Aid*

BY MACK L. CLAYTON, M.D., ARTHUR W. TROTT, M.D., AND ROBERT ULIN, M.D.,
VETERANS ADMINISTRATION

From the Section on Orthopaedic Surgery, Cushing Veterans Administration Hospital, Framingham, Massachusetts

Recurrent subluxation of the ankle, caused by torn lateral ligaments, is more common than realized. Many an acute "sprained ankle" is in reality a complete tear of the lateral ligaments; and, unless treated by immobilization in plaster, recurrent subluxation will follow. Leonard recently found that twenty-three of fifty-one severely sprained ankles were actually complete ligamentous tears; in the same article are given excellent illustrations of the anatomy of the lateral ligaments with roentgenograms revealing the instability resulting from a severance of individual lateral ligaments. Watson-Jones has placed emphasis on an accurate diagnosis and has recommended treatment of the recurrent condition by peroneal brevis tenodesis in which the proximal end of the tendon is used to reconstruct new ligaments.

FIG. 1
Photograph showing the forced inversion of the ankle by the surgeon at the time of making the roentgenogram.

Diagnosis is based on a history of a sprained ankle followed by repeated "twisting" or "giving way" of the ankle, especially on irregular ground or when wearing shoes with heels worn down on the outside. Many patients will say they have "weak ankles" or "chronic sprained ankles".

In a pronounced case, forced inversion of the foot will reveal a definite, palpable sulcus between the talus and the fibula. Most cases, however, will not definitely show this, and the diagnosis must be based on roentgenographic examinations of the ankle with the foot in forced inversion. It is important that the peroneal muscles be relaxed so that only the lateral ligaments are holding the talus in position. To make certain of this in an acute or chronic case, we have, as a matter of routine, made roentgenograms of the ankle in forced inversion under peroneal-nerve block. The procedure is simple, safe, and efficient, and it may be performed as an office or out-patient procedure. Five to ten cubic centimeters of 2 per cent. procaine is injected around the peroneal nerve where it may be felt passing beneath the head of the fibula. Peroneal paralysis follows in from five to ten minutes; and painless, unresisted inversion of the ankle is possible with all factors of

* Published with permission of the Chief Medical Director, Department of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or the conclusions drawn by the authors.

resistance excluded except those of the lateral ligaments (Fig. 1). The surgeon himself should perform the inversion in order to make certain that the roentgenogram is made in the desired position. We have used peroneal nerve blocks in over twenty cases with uniformly successful results. We believe it is a safer and more reliable procedure than the injection of procaine locally around the ligaments. Even with local injection there is often

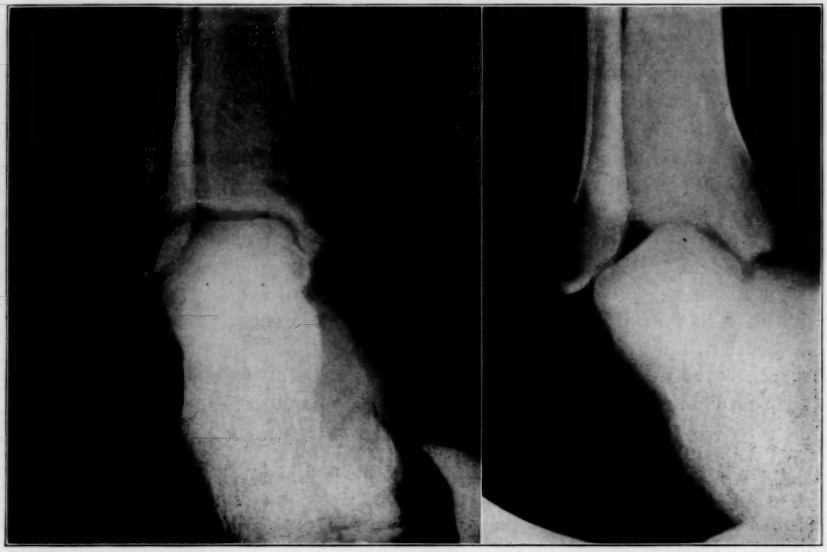


FIG. 2

Roentgenograms of the ankle in inversion under peroneal-nerve block, made before the operation and nine months after the operation.

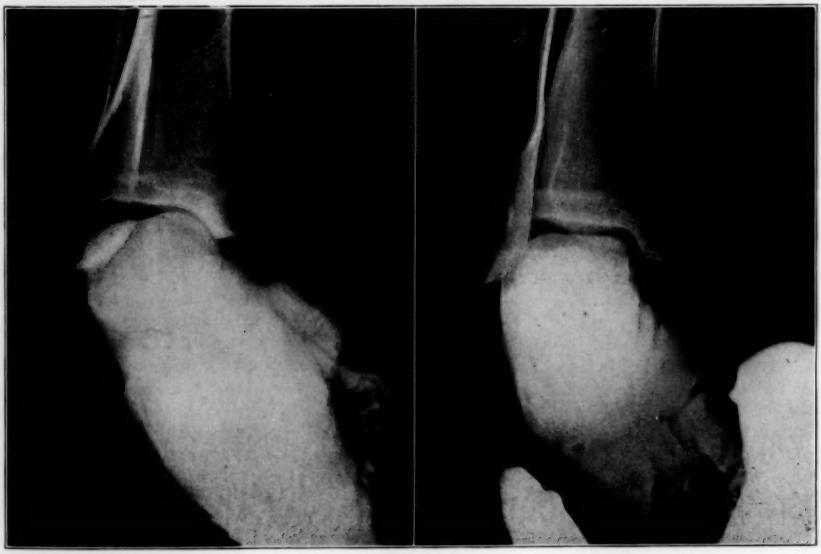


FIG. 3

Roentgenograms of the ankle in forced inversion, before the operation and one year after the operation.

an element of peroneal spasm which cannot be completely overcome. In an acute case, if there is a ligamentous tear, the hematoma will communicate with the joint. One of the authors has seen one case of septic arthritis following procaine injection of a sprained ankle. Peroneal-nerve block has also been used to test for tibiofibular diastasis in severe ankle injury, the roentgenograms made with the talus in a forced lateral position.

We have performed Watson-Jones' peroneal brevis tenodesis in seven chronic cases with lateral instability. Five cases have been followed for over one year. All patients have been relieved of twisting of their ankle and have been satisfied with the result of the operation. The younger patients have been active in athletics without symptoms.

The following questions have been raised about the procedure:

1. Do the newly constructed ligaments stretch in time?
2. Is normal ankle motion interfered with by the procedure?

In answer to the first question, we can but say that all patients examined after the operation have had clinically stable ankles. One year after the procedure, we made roentgenograms of the ankles of three patients in forced inversion; and, in all three, the talus has been found to be stable (Figs. 2 and 3).

As far as the second is concerned, all patients who have been examined after the operation have had a full range of ankle motion, both actively and passively.

One patient, however, complained of an "aching" in the ankle after exercise or in damp weather; this patient had an ankle with a history of five years of repeated subluxation which probably had given rise to a mild degree of traumatic arthritis (Fig. 2).

REFERENCES

LEONARD, M. H.: Injuries of the Lateral Ligaments of the Ankle. J. Bone and Joint Surg., **31-A:** 373–377, Apr. 1949.

WATSON-JONES, REGINALD: Fractures and Joint Injuries, Ed. 3, pp. 769–772. Baltimore, Williams and Wilkins Co., 1946.

DISCUSSION

THE USE OF MUSCLE RELAXANTS

(*Continued from page 501*)

In answer to Dr. Neufeld's question about rate of injection, 100 cubic centimeters of the 2 per cent. solution is the average dose. We give it either by the drop method or by the direct injection with 50-cubic-centimeter syringes. It is given slowly enough so that the signs we described in the paper come on slowly. When given more abruptly, there may be a marked effect on the bowels with such unpleasant symptoms as nausea and vomiting. I have never seen any really serious deleterious effects from 100 cubic centimeters of the drug to date. The 100 cubic centimeters is usually given in about five minutes, rapidly enough so that the effect is maintained, but not fast enough to abruptly bring on toxic symptoms.

In regard to the question of specificity of effect in various conditions, it has been shown that conditions of central origin respond more rapidly. Tremor and rigidity respond almost instaneously. Apparently the bulbar reticular substance is of critical importance in the inhibition and facilitation of many of these motor patterns, and thus it is most sensitive to the effect of the drugs. True spasticity, secondary to cord transection, is much less sensitive unless approximately twice the dose is given as in the previously mentioned disorders. As I said before, the short reflex arcs in the cord are much more difficult to influence than the brain stem mechanisms. True muscle spasm responds almost as rapidly as tremor and rigidity.

So far as allergies are concerned, I have never seen any when the drug was given intravenously, possibly for lack of sufficient acumen to recognize them. We have used the drug a great deal to study the reversibility of contractures in our cases at the Institute for the Crippled and Disabled, and as an adjunct to traction and the reduction of dislocation of the spine. We think it has a real place in orthopaedic and neurological practice. I do not believe that the drug is useful by mouth in spite of many reports to the contrary.

In reply to the question from the floor as to the feasibility of the use of the intravenous preparation in the office or home, I have never seen fit to use it except under complete hospital control. Any drug which can paralyze a patient or cause some of the signs and symptoms which we have described probably has no place in office practice, unless one has a set-up which is essentially that of an overnight ward.

INFANTILE ANKYLOSIS OF THE TEMPOROMANDIBULAR JOINT

Treatment by Resection of Mandibular Condyle

BY LIEUTENANT COLONEL THAYNE F. McMANIS, *Dental Corps*, AND
LIEUTENANT COLONEL ERNST DEHNE, *Medical Corps, United States Army*

From the Dental and Orthopaedic Services, Oliver General Hospital

Ankylosis of the temporomandibular joint has been discussed by Parker, Kazanjian and Converse, Straith and Lewis, Dingman, Thoma, and Kelikian. When the condition occurs in the infant, it not only prevents opening of the mouth, but leads to marked distortion of the face by growth deformity and atrophy of the disused muscles as the child develops. Surgical correction is the only treatment for this condition. The time of surgery is, however, still controversial. Kanthak and Hamm pointed out that resection of the condyle at an early age will destroy the growth center and may lead to further deformity by lack of normal down growth of the vertical ramus. Most authors, however, feel that the stimulus obtained from the normal stresses of mastication and proper use is more important to promote growth and development.

In the case described here, the authors felt that the growth center had already been considerably damaged and that its preservation was of questionable value. Immediately following surgery, normal functional stress during mastication was stimulated by the use of a training flange attached to the lower teeth. This appliance was adapted after the procedure suggested by Fry and his associates in the treatment of mandibular deviation resulting from unilateral fracture-dislocation of the mandibular condyle.

The patient was an eight-year-old white girl of Italian descent. The deformity of her face and inability to open the mouth had been first noticed by her family when she was two years of age. No history of trauma or of infection after birth could be elicited.

The patient had marked asymmetry of the lower third of her face with deviation of the chin to the right and flattening and depression of the jaw on the left (Fig. 1). The opening of the mouth was limited to 1 centimeter and was associated with lateral deviation to the right of about 0.5 centimeter (Fig. 2). There was normal excursion of the mandible to the right, but the left lateral excursion was negative. The dentition was normal for the child's age except for absence of the lower permanent first molar on the right. There was cross-bite malocclusion on the right; the teeth on the left had a vertical inclination to the right

FIG. 1

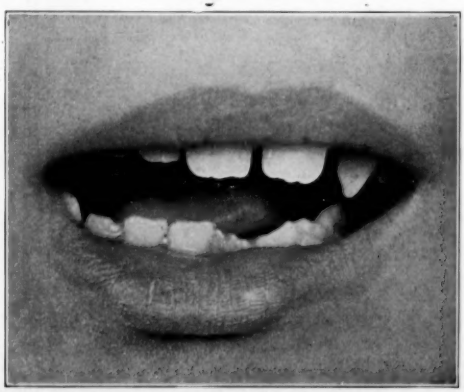


FIG. 2

Fig. 1: Photograph of patient before operation, showing marked asymmetry of lower third of face and deviation of chin to the right.

Fig. 2: Demonstrating maximum opening with lateral deviation of mandible.

FIG. 3-A

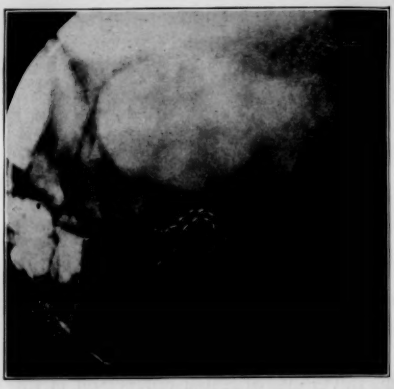


FIG. 3-B

Roentgenograms show (Fig. 3-A) the right condyle malformed and poorly demonstrated because of extensive fibrosis and (Fig. 3-B) the left condyle normal.

FIG. 4

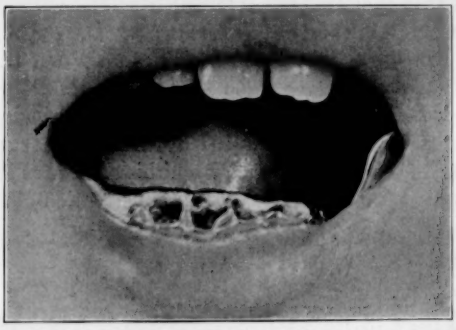


FIG. 5-A

Fig. 4: Illustration of appliance, as described by Fry and his associates.

FIG. 5-B

Figs. 5-A and 5-B: Photographs of patient with mouth open following condylectomy, showing the appliance used for muscle training.

with a normal occlusal relation. Digital examination revealed normal motion of the temporomandibular joint on the left, none on the right.

Multiple roentgenographic studies revealed ankylosis of the right temporomandibular joint, but the definition of the lesion was not entirely clear (Figs. 3-A and 3-B).

Study models of both jaws were obtained and a vertical training flange was constructed for postoperative repositioning and to permit immediate training of the muscles (Fig. 4).

The mandibular condyle was resected through a pre-auricular incision, extending upward from the proximal end of the external acoustic meatus. Fibrous ankylosis of the joint was encountered. After resection of the head of the condyle at the level of the mandibular notch, the mouth was opened to a satisfactory distance.

The absence of postoperative discomfort was surprising; the patient could open her mouth as wide the day after operation as on the preceding day, when she was under anaesthesia (Figs. 5-A and 5-B). Within five days, she was able to take a regular diet and to open her mouth 2.5 centimeters. The training splint

FIG. 6

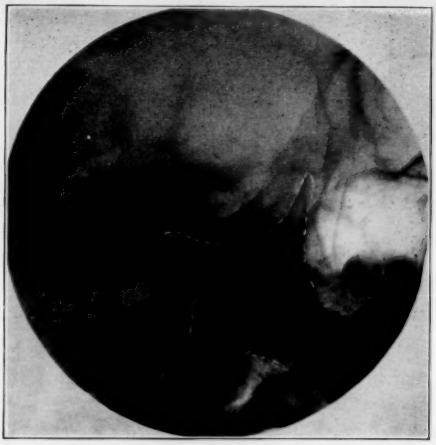


FIG. 7

Fig. 6: Photograph of patient, five days after operation, demonstrating marked improvement in facial contour.

Fig. 7: Postoperative roentgenogram of the right temporomandibular joint space. The right condyle has been amputated; joint space is more clearly demonstrated.

was well tolerated, and within a few days both the position of the jaw and the facial contour had improved markedly (Fig. 6). Postoperative roentgenograms showed radiolucent space between the temporal bone and the ramus of the mandible, as well as absence of the right condyle (Fig. 7).

The patient was followed closely and further adjustments were made on the training appliance. She gained motion of the jaw to the left. The opening improved to 3 centimeters within four months after operation. Cross-bite on the right side, as well as the general appearance of occlusion, was corrected. The lower permanent six-year molar was erupting on the right side. Maximum benefit from the training flange had been obtained after four months.

This patient had been seen and treatment had been attempted in numerous hospitals over a period of six years. Even while under the authors' evaluation, surgery was advised against by most of the consultants for fear that an operation at her age would result in increased deformity. The postoperative course indicates that restoration of normal function decreased the deformity and stimulated the eruption of a retarded tooth. We, therefore, feel assured that the procedure has not harmed the patient. In addition, her mental outlook has been greatly improved. We also feel that, to obtain maximum beneficial results, close cooperation between the dental surgeon and the orthopaedic surgeon is important.

REFERENCES

DINGMAN, R. O.: Ankylosis of the Temporomandibular Joint. Am. J. Orthodont. and Oral Surg. (Oral Surgery Section), **32:** 120–125, 1946.

FRY, W. K.; SHEPHERD, P. R.; MCLEOD, A. C.; and PARFITT, G. J.: The Dental Treatment of Maxillo-Facial Injuries. With Supplementary Material on Cases and Techniques, pp. 105–106. Philadelphia, J. B. Lippincott Co., 1943.

KANTHAK, F. F., and HAMM, W. G.: Surgical Treatment of Growth Deformities of the Mandible. Southern Surgeon, **14:** 147–153, 1948.

KAZANJIAN, V. H., and CONVERSE, J. M.: The Surgical Treatment of Facial Injuries. Baltimore, Williams and Wilkins Co., 1949.

KELIKIAN, H.: A Method of Mobilizing the Temporomandibular Joint. J. Bone and Joint Surg., **32-A:** 113–131, Jan. 1950.

PARKER, D. B.: Ankylosis of the Temporomandibular Joint. J. Oral Surg., **6:** 42–50, 1948.

STRAITH, C. L., and LEWIS, J. R.: Ankylosis of the Temporo-Mandibular Joint. Plastic and Reconstructive Surg., **3:** 464–477, 1948.

THOMA, K. H.: Oral Surgery, Vol. II. St. Louis, C. V. Mosby Co., 1948.

A METHOD OF INTERNAL FIXATION FOR THE McMURRAY TYPE OF INTERTROCHANTERIC OSTEOTOMY

BY O. SHERWIN STAPLES, M.D., HANOVER, NEW HAMPSHIRE

From the Section of Orthopaedic Surgery, Hitchcock Clinic and Mary Hitchcock Memorial Hospital, Hanover

The intertrochanteric osteotomy described by McMurray and, in modified form, by Leadbetter, particularly because of its relative simplicity, has had a place in the treatment of non-union of fractures of the neck of the femur for several years. However, when the operation is used, one serious disadvantage has been the postoperative need for a plaster spica cast. This postoperative fixation, necessary until the osteotomy has united, not only predisposes the patient to serious general complications, but also leads to a long-lasting, and sometimes to a permanent, dysfunction of the immobilized knee and foot.

With this in mind, an osteotomy nail was devised to provide sufficient internal stability so that the plaster spica cast could be eliminated and replaced by a balanced splint, allowing early mobilization of the knee and foot.

Blount and Key have described methods of internal fixation of an intertrochanteric osteotomy, the former using his blade plate and fixing the trochanteric fragment in valgus, and the latter fixing the two osteotomy fragments with a transfixion screw. Neufeld, according to Blount, has also used a blade plate for fixing the osteotomy fragments.

The advantages of the device to be described are its simplicity and its ease of inser-

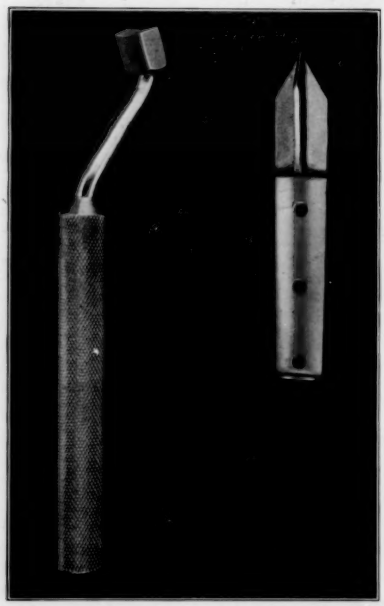


FIG. 1

FIG. 2

Fig. 1: Intertrochanteric osteotomy nail and nail driver.

Fig. 2: L. S. At open operation, it was impossible to fix the head with a nail because of a very high fracture. The osteotomy done was of the Leadbetter type. Roentgenogram shows status eight weeks after osteotomy. Walking was started seven weeks after osteotomy.

tion. Only one size nail is required, and no bending or shaping need be done. The device can be used for both the McMurray and Leadbetter types of osteotomy. It also facilitates the impaction of the osteotomized surfaces.

The osteotomy nail (Fig. 1), made of Vitallium, consists of a three-flanged segment which is driven into the cancellous bone of the greater trochanter and a plate extension which is fixed to the femoral shaft by three Vitallium screws.

The operation can be performed through a lateral incision over the trochanter or through a Smith-Petersen incision extended distally and laterally to section the fascia lata. After the distal osteotomy fragment has been moved medially and positioned properly, as described by McMurray and Leadbetter, the osteotomy nail is inserted. The nail is placed in contact with the femoral shaft and held by hemostatic clamps. The nail is driven into the cancellous bone of the greater trochanter by a mallet and a bayonet-shaped driver (Fig. 1), which is held against the base of the three-flanged portion, until the tip of the nail begins to engage the proximal cortex. During this procedure, the nail must be held in contact with the surface of the distal fragment. Since the nail is curved to conform to the rounded shaft of the femur, this is not difficult. The bayonet-shaped driver is helpful, but an ordinary bone set can be used almost as easily.

The bent-up distal tip of the nail can be used for extraction of the nail if this becomes necessary. This is done by engaging the end of the driver against the bent-up distal tip from the proximal side, and, with the use of the mallet, the nail comes easily out of the greater trochanter.

When the nail is in good position, a bone-holding forceps is used to hold the nail against the femoral shaft, and three Vitallium screws, engaging both cortices, are inserted to fix the plate extension to the distal fragment. Following this, the osteotomy is impacted by engaging the driver against the turned-up tip of the plate from the distal side and striking it with several blows of the mallet.

At the completion of the operation, the affected hip is maintained in 30 or 40 degrees of abduction, in neutral rotation, and in approximately 30 degrees of flexion and held by means of a balanced Thomas or Hodgen splint with a Pearson attachment. Usually five pounds of adhesive skin traction is applied to the leg and maintained for one or two weeks. Position in bed is important, so that adduction of the hip operated upon does not take place.

Active exercises for the foot and ankle can be started at any time along with quadriceps-setting exercises. To these may be added, ordinarily at the end of two weeks, passive flexion and extension of the knee, done manually by the patient by means of a rope-pulley arrangement attached to the end of the Pearson attachment.

At the end of seven weeks, there is usually sufficient healing to allow the removal of the apparatus and the institution of walking in a walker with mild weight-bearing. Change is then made to crutches, and finally a cane, when the patient is functionally ready. More extensive exercises for hip and knee may be added when the splint has been removed.

This osteotomy nail has been used in five patients, all with fractures of the neck of the femur, varying in duration from one week to one year. It has been used only when other, more direct, methods, such as hip nailing, cannot be applied because of anatomical problems or non-union. In all patients the osteotomy itself was maintained by the osteotomy nail, and in none was there troublesome or lasting knee dysfunction.

REFERENCES

BLOUNT, W. P.: Blade-Plate Internal Fixation for High Femoral Osteotomies. J. Bone and Joint Surg., **25**: 319–329, Apr. 1943.

KEY, J. A.: Internal and External Fixation of High Osteotomies of the Femur. J. Bone and Joint Surg., **25**: 737–744, Oct. 1943.

LEADBETTER, G. W.: Cervical-Axial Osteotomy of the Femur. J. Bone and Joint Surg., **26**: 713–720, Oct. 1944.

MCMURRAY, T. P.: Ununited Fractures of the Neck of the Femur. J. Bone and Joint Surg., **18**: 319–327, Apr. 1936.

MCMURRAY, T. P.: Fractures of the Neck of the Femur Treated by Oblique Osteotomy. British Med. J., **1**: 330–333, 1938.

SEPTIC CHONDRITIS OF THE COSTAL CARTILAGE

A CASE REPORT

BY NED M. SHUTKIN, M.A., M.D., AND JAMES M. CARY, M.D., NEW HAVEN, CONNECTICUT

From the Section of Orthopaedic Surgery, Department of Surgery, Yale University School of Medicine, New Haven

On various occasions, orthopaedic surgeons are confronted with a local swelling on the anterior wall of the chest, usually near the sternoclavicular joint, which presents a baffling diagnostic problem and frequently remains undiagnosed because of eventual spontaneous remission. In the differential diagnosis, septic chondritis of the costal cartilage is insufficiently appreciated as a cause of tumefaction of the anterior chest wall. Its current obscurity has been brought about by the triumph over typhoid fever which formerly was the most frequent cause of septic chondritis. However, its occurrence is not so rare as is indicated by the paucity of reference to it in the current literature and textbooks. Failure to recognize the condition stems from several factors. The onset may be slow and insidious, without outstanding local and constitutional evidence of infection. The septicaemia providing the hematogenous inoculation may be transient and asymptomatic, or may so precede the chondritis that the relationship is not appreciated. Brock reported a case of paratyphoid chondritis of the clavicle in a patient, not a proved carrier, who had had paratyphoid fever fourteen years previously.

The not infrequent spontaneous subsidence of the process without suppuration adds to the difficulty in establishing the diagnosis. Furthermore, the symptoms and findings from the secondary involvement of contiguous tissues by the infectious process may disguise the primary focus. Bisgard cited a case of chondritis of the first rib in which pain, weakness, numbness, and paraesthesia in the upper extremity, due to involvement of the brachial plexus, preceded by four months any local manifestations of infection of the costal cartilage. The radiolucency of cartilage hindered roentgenographic diagnosis.

Etiology

Acute septic chondritis is usually caused by one of the common pyogenic organisms, the *Staphylococcus aureus* being the most frequent offender. Other organisms producing chondritis of a more chronic, indolent nature are the tubercle bacillus, the *Treponema pallidum*, and certain fungi, particularly *Actinomyces* and *Blastomyces*.

The mode of infection is usually hematogenous, although it may also arise by spread from contiguous infected tissues or by direct bacterial implantation into a penetrating wound.

Morbid Anatomy

In septic chondritis of hematogenous origin, the bacterial embolism occurs in the vascular perichondrium rather than in the cartilage proper, since the latter is an avascular

tissue. The infection begins as a subperichondral process which may spread in all directions. The subperichondral accumulation of exudate dissects the perichondrium away from the cartilage. Grossly, the perichondrium is seen to be thickened and inflamed, and may show single or multiple sites of perforation or even more extensive, diffuse destruction. Microscopically, granulation tissue or pus, or both in varying amounts, are seen between the perichondrium and the cartilage. The cartilage proper is darkened, eroded, and necrotic. Multiple small abscesses may be seen, with bits of necrotic cartilage contained in the pus[3].

Symptoms

The onset and character of the symptoms may be those of a full-blown infection, but it is not unusual for the clinical picture to be consistent with some other pathological process, particularly that of a malignant tumor. This is particularly true of those cases in which the onset is slow and insidious without a history of the infection, and where local pain and swelling are the salient features. Fever and leukocytosis may be low-grade.

The process may undergo spontaneous subsidence or may progress to abscess formation with spontaneous rupture and discharge. The extent of the involvement may be a reflection of the anatomy of the costal cartilage primarily involved. The five upper pairs articulate with the sternum and usually contain the infection locally. This is also true of the two lowest pairs which have free ends. However, the sixth through the tenth cartilages articulate with a common cartilage which may provide the avenue for a generalized spread of the infection.

Diagnosis

In those cases which manifest the classical signs of infection and suppuration, particularly with spontaneous rupture, diagnosis presents no problem. Whether the chondritis is primary or whether it is secondary to undetected infection in contiguous tissue should be determined so that a proper regimen of therapy can be instituted. In those cases in which there is a localized painful tumefaction with a subdued local and constitutional reaction, such as a low-grade fever, mild leukocytosis, and an only slightly increased erythrocyte sedimentation rate, the presence of malignant growth must be considered. The neoplasm may be primary in the cartilage or bone, or may be metastatic from the underlying pulmonary or mediastinal structures. When the left clavicle or the first rib is involved, a local spread from a sentinel supraclavicular gland bearing metastases from a gastric carcinoma must be considered. Lymphadenopathy in that region from other causes must also be considered. An eroding aneurysm is another possibility.

Treatment

Treatment formerly consisted solely of total subperichondral resection in those cases where spontaneous subsidence seemed unlikely. In the case of infection of any one of the second five pairs of ribs, complete resection of the quintet, including the common articulating portion, was advocated. This applied to a tuberculous as well as to a pyogenic infection.

Recent advances in chemotherapy have led to a more conservative attitude, with surgical supplementation of the drug consisting of aspiration or of a simple incision and drainage, unless rapid destruction is occurring. The efficacy of chemotherapy, with or without local drainage, still remains to be proved.

A single case, illustrative of some of the difficulties in establishing the diagnosis, is presented:

CASE REPORT

A colored man, sixty-three years old, was seen in the Emergency Room of the New Haven Hospital in March 1950, with the chief complaint of a painful swelling, of three days' duration, of the left upper chest

wall anteriorly, in the region of the left sternoclavicular joint. He gave a history of having been struck over this region by a 100-pound bag of flour about one week previously, and of having had a tooth extracted from the left lower jaw five days previously. Rectal temperature was 101 degrees. Aspiration with a 17-gauge needle failed to yield any material that provided a diagnostic clue. X-ray studies with laminagrams revealed what was interpreted as fragmentation of the cartilage of the first rib on the left, and an anomalous junction between the sternal body and the manubrium. The man was instructed to return home and to apply heat to the swelling.

Examination two days later revealed the swelling to be firmer, smaller, and considerably less tender. Oral temperature was 98 degrees. The patient was instructed to return in two weeks.

However, he next appeared in the Emergency Room nine days later, at two o'clock in the morning, because of a recurrence of severe pain at the site of the swelling. The mass was hard and very tender, and somewhat larger than when seen previously. Oral temperature was 98.4 degrees.

The patient was seen by the Orthopaedic Service, and hospitalization for diagnostic differentiation was advised. The consensus favored the presence of a malignant growth, probably of some thoracic structure, and the patient was transferred to the Thoracic Surgery Service.

The work-up of the case revealed the additional information that the patient had suffered considerable weight loss, amounting to about thirty pounds, during the preceding six months; that he had been having mild dysphagia for several weeks; and that he had spit up blood and had had tarry stools recently. He was unable to state whether he had actually coughed up or vomited blood, or whether it was mere expectoration of bloody saliva following the tooth extraction. Noteworthy clinical findings were as follows: rectal temperature 101.2 degrees; pulse, 96 per minute; respirations, 20 per minute; blood pressure, 142 systolic, 100 diastolic. There was the previously described firm, exquisitely tender, warm swelling over the region of the left sternoclavicular joint. Lung fields were clear to percussion and auscultation. There was a moderate cardiac enlargement to the left, with a blowing presystolic murmur over the mitral area. All other clinical findings were negative or non-contributory.

Laboratory examinations revealed the following:

Red blood cells		3,660,000
White blood cells		10,600
Segmented neutrophils	71 per cent.	
Lymphocytes	26 per cent.	
Monocytes	3 per cent.	

Corrected erythrocyte sedimentation rate was 28 millimeters per hour. Blood-chemistry determinations were within normal limits. Total serum protein was 8.71 milligrams per 100 cubic centimeters of blood (serum albumin, 2.61 and serum globulin, 6.10). Bence-Jones protein was not detected in the urine. Fasting gastric analysis revealed no free hydrochloric acid and 13.5 units of combined hydrochloric acid. Guaiac test for blood was negative. Serology was negative. First strength purified protein derivative was negative after forty-eight hours; second strength was + + +. Sternal-marrow biopsy was negative.

Agglutination tests and blood cultures for typhoid, paratyphoid, and *Salmonella* organisms were negative. Blood cultures for pyogens and *Brucella* organisms were also negative.

Roentgenograms were made repeatedly and revealed some haziness of the left upper lung field and a slight deviation of the trachea to the right. There was a definite elevation of the diaphragm on the left, presumably due to phrenic-nerve involvement, and disc atelectasis of the left lower lobe. A roentgenographic survey of the entire skeleton failed to reveal any other abnormal findings.

In the differential diagnosis, the following were considered: primary malignant growth of mesenchymal origin; metastatic malignant growth derived from the stomach, oesophagus, or the pulmonary structures; multiple myeloma; infection of undertermined etiology, either hematogenous or from local extension.

The diagnosis was established by a biopsy which showed the costal cartilage of the first rib on the left to be involved. The pathologist's report was "acute inflammatory reaction with abscess formation". Culture revealed a *Streptococcus hemolyticus* to be the offending organism.

During the study of the case, the lesion underwent spontaneous improvement, with a decrease in size and tenderness. The patient's temperature and leukocyte count returned to normal. Following the biopsy, the patient was given penicillin therapy for three days, which resulted in a continued progressive subsidence of the local process. The patient was discharged twenty-five days after admission.

REFERENCES

1. Bisgard, J. D.: A Case of Tuberculous Osteomyelitis and Chondritis of the First Rib. Am. J. Surg., **44:** 450–452, 1939.
2. Brock, R. C.: Post-Typhoid Chondritis with Abscess Formation. British J. Surg., **23:** 231–232, 1935.
3. Hener, G. J.; Andrus, W. DeW.; Barnes, W. A.; and Eckel, J. H.: Surgery of the Thorax, pp. 403–408. *In* Nelson Loose Leaf Living Surgery. New York, Thomas Nelson and Sons, 1948.
4. Siler, V. E.: Acute Costal Chondritis Associated with Sternal Osteomyelitis. Surgery, **12:** 407–410, 1942.

COXOMETER *

BY JAMES A. DICKSON, M.D., JAMES B. WOODRUFF, M.D., AND JOHN F. RUDOLPH, M.D.,
CLEVELAND, OHIO

When performing arthrodesis of the hip joint or corrective osteotomy of a fused hip, there is always the problem of properly placing the limb to assure maximum function. With the patient on the operating table and the bony landmarks obscured with drapes, it is difficult to estimate the degree of lumbar lordosis and the relationship of the pelvis to the femur. The use of a special coxometer has helped to minimize these difficulties. The relative position of the adductor tubercle (Fig. 1,*D*) to three fixed points on the pelvis, the two anterior superior iliac spines and the symphysis pubis (Fig. 1,*A*, *B*, and *C*), will determine the degree of flexion and abduction of the hip. Any desired position of flexion and abduction can be recorded on the coxometer scales (Fig. 1,*E* and *D*) and can be accurately reproduced under operating-room conditions, regardless of flexion of the lumbar spine or pelvic tilt.

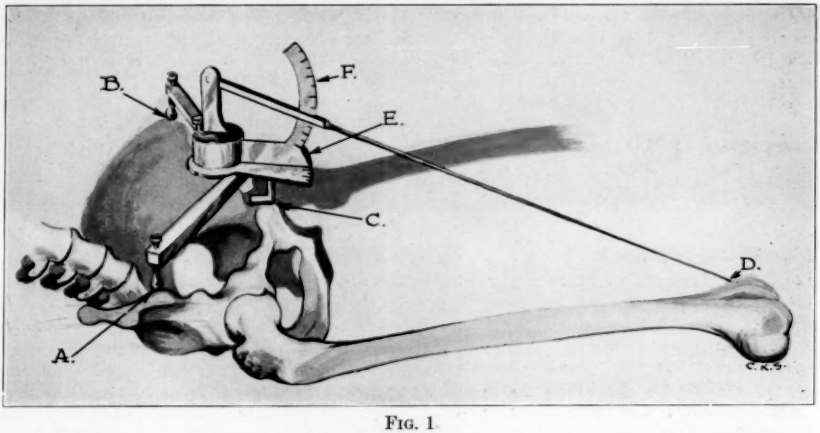


FIG. 1

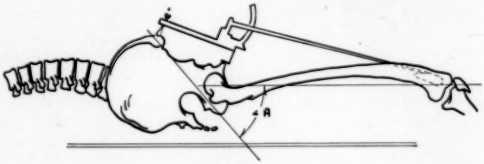


FIG. 2

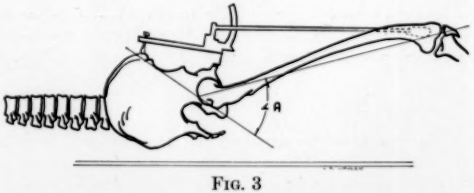


FIG. 3

FIG. 4

FIG. 5

Figs. 2 and 3: Show that the relationship of the pelvis to the femur in the sagittal plane (angle *A*) remains the same regardless of flexion or extension of lumbar spine.

Figs. 4 and 5: Illustrating that this relationship (angle *B*) is unaffected by pelvic tilt.

* Presented in Gadget Exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 11 to 16, 1950.

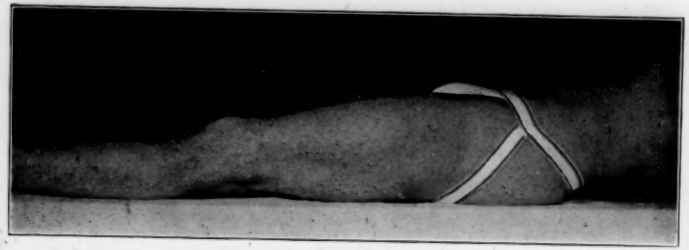


FIG. 6

The patient's lumbar spine is in some lordosis and the relationship of the lower extremity to the pelvis is unknown.

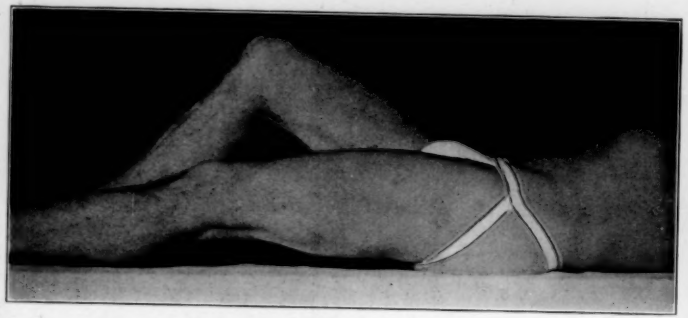


FIG. 7

The lumbar spine is flattened on the table by flexing the unaffected hip.* If the lower extremity is brought parallel to the table, it will be in full extension (180 degrees).

* When the hip is partially ankylosed or is ankylosed in poor position, the lumbar spine is flattened by bringing the thigh into sufficient flexion to eliminate the lordosis, and the measurements are made on the unaffected extremity.

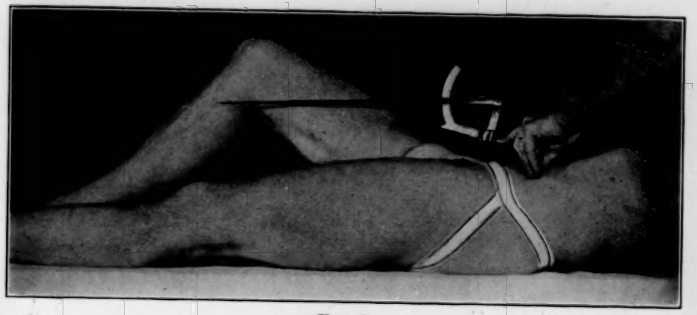


FIG. 8

The coxometer is applied to the patient. The pointer is brought into a horizontal plane by means of direct vision or by using a spirit level. Thus the pointer is parallel to the lower extremity and indicates the position of full extension.

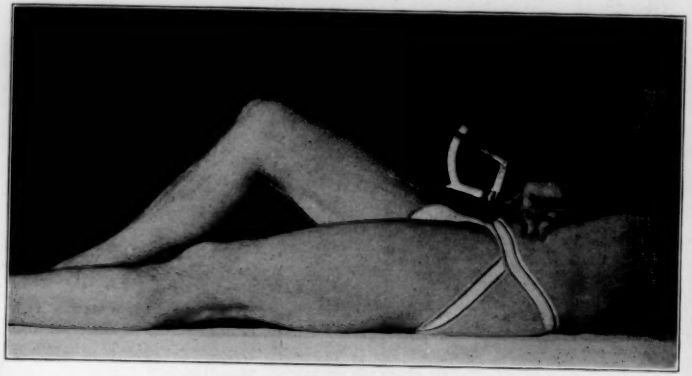


FIG. 9-A

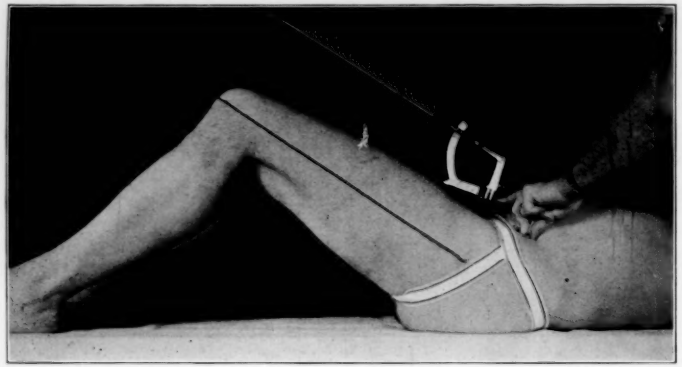


FIG. 9-B

Figs. 9-A and 9-B: The pointer is elevated to the desired angle of flexion (30 degrees) and the axis of the thigh is brought parallel to this. Thus the femur is also flexed 30 degrees on the pelvis.

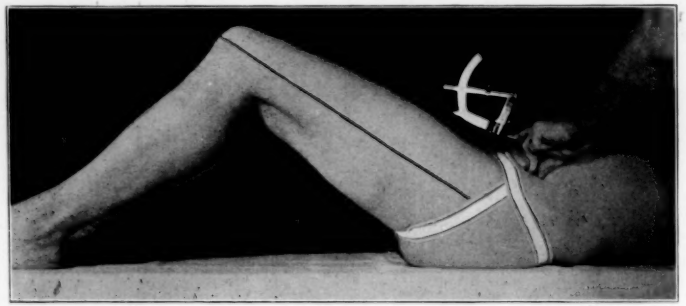


FIG. 10

With the lower extremity held in this position of flexion, the pointer is moved to the adductor tubercle. The final reading on the vertical protractor is recorded. (This angle of flexion of the femur on the pelvis may be reproduced by setting the pointer at the recorded position and placing the adductor tubercle in contact with the pointer.)

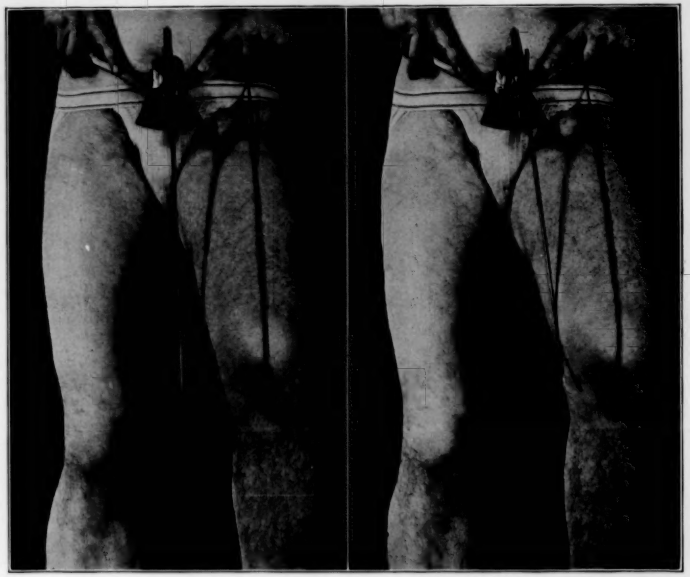


FIG. 11 FIG. 12

Fig. 11: In a symmetrical pelvis, a line running perpendicular to the midpoint of a line between the anterior superior iliac spines serves as a guide to the degree of abduction or adduction of the lower extremity. If the axis of the lower extremities is brought parallel to this line, indicated by the pointer, the axis is assumed to be in the neutral position. (The axis of the lower extremity is defined as a line from the center of the femoral head through the center of the patella to the first interosseous space of the foot. For practical purposes a line from the anterior superior iliac spine—which is more readily identified than the femoral head—through the patella to the first interosseous space is used. This produces approximately 3 to 4 degrees of abduction of the limb.

Fig. 12: If arthrodesis is desired in this neutral position, the pointer is placed on the adductor tubercle and the final reading on the horizontal protractor is noted. If a position of abduction or adduction is desired, the pointer is deviated the necessary amount and the axis of the lower extremity is brought parallel to

(*Continued on page 516*)

Fig. 12: (*Continued*)

it. With the limb maintained in this position, the pointer is placed on the adductor tubercle and the final reading is noted. Thus, the desired angle of abduction or adduction may be reproduced by resetting and replacing the pointer on the adductor tubercle.

The coxometer described here consists of a base with three projections on the under surface which rest on the two anterior superior iliac spines (Fig. 1,*A* and *B*) and the symphysis pubis (Fig. 1,*C*). The arms of the base are adjustable, so it can be adapted to a pelvis of any size. On this base is mounted a long pointer with horizontal and vertical protractors (Fig. 1,*E* and *F*). The pointer is used to register the location of a fourth point, the adductor tubercle (Fig. 1,*D*), which varies in relation to the other three points, depending upon the position of the hip. The relative position of the adductor tubercle to the three fixed points of the pelvis (Fig. 1,*A*, *B*, and *C*) determines the degree of flexion and abduction of the hip. Any desired position of flexion, abduction, or adduction can therefore be reproduced with the aid of the coxometer.

The foregoing illustrations (Figs. 6 to 12) show the method of determining the proper placement of the limb to assure ankylosis in position of 30 degrees of flexion and neutral abduction and adduction. Any other position could be calculated in a similar manner. The patient is placed on an unpadded examination table so that the position of the lumbar spine can be determined. The calculations are made the day before operation, and the readings on the vertical and horizontal protractors are recorded. When the hip joint has been exposed at operation, the coxometer, which has been sterilized and reset, is applied to the lightly draped pelvis. The desired position of the hip is reproduced by bringing the adductor tubercle up to the pointer. The extremity is then fixed in this position on the fracture table and internal fixation, either alone or associated with grafting, is completed. The same principles are used for high corrective osteotomies for fused hips with malposition.

COMMENT

1. When limitation of motion prevents placing the involved extremity in the ideal position, the coxometer may be applied to the opposite extremity and the readings transposed so that they will apply to the involved side. The uninvolved femur is placed in ideal relationship to the pelvis for fusion or osteotomy. The coxometer is applied to the pelvis and uninvolved femur. In transposing, the reading on the vertical scale remains the same. The horizontal-scale reading is transposed to the involved side. If the horizontal reading is 10 units to the right of the mid-line, the pointer is moved 10 units to the left of the mid-line.

2. The presence of an asymmetrical pelvis precludes accurate preoperative calculations. However, the desired position of the hip may be determined empirically and then reproduced by means of the coxometer while the patient is on the operating table.

3. The same person should apply the instrument preoperatively and at the time of surgery. Even slight differences in pressure used in applying the instrument over the bony prominences of the pelvis will decrease the accuracy which can be attained.

4. The coxometer may be used to measure the degree of flexion, abduction, or adduction of a fused hip.

NOTE: This article was written at the request of the Editor as a review of the Surgery of War Wounds of the Extremities as developed in the European Theatre of Operations.

CARE OF BATTLE CASUALTIES AND INJURIES INVOLVING BONES AND JOINTS

BY MATHER CLEVELAND, M.D., NEW YORK, N.Y.*, JOHN G. MANNING, M.D., PASADENA, CALIFORNIA **, AND WILLIAM J. STEWART, M.D., COLUMBIA, MISSOURI ***

INTRODUCTION

With the present Korean "incident" and its attendant battle casualties of approximately 50,000, as of March 1951, the mobilization of large numbers of our young men into the Armed Forces and the possible prospect of a total war, it seems essential to record known techniques for the care of the wounded which have had a thorough trial and have been found effective.

In any great national emergency with large numbers of casualties, the supply of completely trained surgeons will never be adequate. For the incompletely trained young surgeons, specific instructions are necessary to secure a high standard of surgical care for the wounded or injured member of the Armed Forces or the civilian.

The following instructions for the care of battle casualties with involvement of the bones and joints were written for a theatre of operations which by the end of the War consisted of 4,000,000 United States troops, 16,000 United States Medical Officers, and more than 260 United States Army Hospitals.

Our civilian population will not be spared in another war, and, in case of massive air attacks, these instructions would apply to the care of the injured on the home front as much as to the care of battle casualties. Treatment at the First Aid Station should be the same as that at the Battalion Aid Station, treatment in the Emergency Hospital should correspond to that at the Army Field or Evacuation Hospital, and treatment in our established civilian hospitals should be equivalent to that in our overseas General Hospitals.

Rapid evacuation of the wounded or injured is usually essential for several reasons. It relieves the forward fighting echelons of the encumbrance of attending the unfit. It promotes good medical and surgical care by removing the sick and wounded back to the installations where such care may be provided. The morale of both the Armed Forces and civilians is enhanced by the realization that every effort is being expended to rapidly return the wounded to a point where adequate medical and surgical care may be provided.

If hospital facilities in an overseas theatre are inadequate, prompt air transportation of the wounded to the Zone of the Interior will allow the institution of accepted surgical reparative procedures,—such as delayed primary closure of wounds and skeletal traction for compound fractures. If long intervals of time elapse, however, the purpose of these techniques may be defeated.

It seems appropriate at this time to submit for publication this revision of that portion of the Manual of Therapy of the European Theatre of Operations which deals with the care of battle casualties and injuries involving the bones and joints.

Care of Battle Casualties and Injuries Involving Bones and Joints

FOREWORD

The Manual of Therapy, European Theatre of Operations, served a useful purpose as a professional guide during the military operations in Europe. Some of the policies of treatment were changed from time to time because of the lessons learned from experience. These changes were published in Circular Letters by the Office of the Chief Surgeon. In an attempt to summarize the principles of orthopaedic treatment which were evolved in the course of the various campaigns in the European Theatre of Operations, those sections of the Manual and the Circular Letters which pertain to bone and joint injuries in battle casualties have been combined. Policies which conflict have been deleted, and a considerable amount of material which appeared to be important prior to the campaigns has been omitted in the interest of brevity.

The material has been divided into three sections:

A. Therapy in Division Installations (Battalion Aid Station, Collecting Company, Clearing Company).

B. Therapy in Army Installations (Field Hospitals, Evacuation Hospitals, Convalescent Hospitals).

C. Therapy in Communication Zone Installations (General Hospitals, Station Hospitals).

* Formerly Colonel, Medical Corps, Army of the United States, and Senior Consultant in Orthopaedic Surgery in the European Theatre of Operations.

** Formerly Lieutenant Colonel, Medical Corps, Army of the United States, and Orthopaedic Consultant for the Ninth Army.

*** Formerly Lieutenant Colonel, Medical Corps, Army of the United States, and Orthopaedic Consultant for the Normandy Base Section.

SECTION A

Therapy in Division Installations (Battalion Aid Station, Collecting Company, Clearing Company)

I. *Strains and Sprains*

1. *Diagnosis:* Great care must be taken to exclude the possibility of fracture. Sharply localized tenderness over bone, rather than ligament, muscle, or tendon, and pain at the site of injury upon manipulation of bones at a distance from the injury are more characteristic of fracture than of sprain. If there is any doubt as to the diagnosis, the patient should be evacuated to an Army hospital where a roentgenographic examination can be made.

2. *Treatment:* The objects of treatment are:

a. To prevent oedema and hematoma formation;

b. To disseminate, for more rapid absorption, any hematomata which have formed.

This is best accomplished by the application of cold (where possible) to the fresh injury, by compression, and by rest to the injured part. Heat in any form as a primary treatment is illogical and harmful and *should not be applied.*

All patients with strains and sprains which do not respond rapidly to conservative treatment should be evacuated to the rear. Treatment of moderate and severe sprains of the major joints and of the back should not be attempted in the forward areas.

II. *Dislocations*

No attempt should be made to manipulate or reduce dislocations prior to a roentgenographic examination or without anaesthesia. Pain should be relieved with morphine. The patient should be placed in a litter and the affected part splinted by use of folded blankets in the position of maximum comfort. The patient should then be transferred as rapidly as possible to an Evacuation Hospital.

III. *Simple Fractures*

Simple fractures should be splinted. These patients should be transported to the Evacuation Hospital as soon as conditions will permit, but in general these are low priority evacuation cases.

IV. *Compound Fractures*

The following suggestions are made for the initial handling of patients with compound fractures due to battle injuries:

1. *Examination:* A rapid but careful examination of the patient should be made to determine the site of the injury or injuries, so that proper splinting can be applied. It is not advisable to remove the clothing from the patient for this examination. Each extremity should be examined separately, and the thorax and the back should be checked carefully.

2. *Treatment*

a. Shock should be treated promptly by infusion of plasma or blood.

b. Morphine should be administered in sufficient quantities to relieve pain, but morphinism must be avoided. Subcutaneous injections of morphine are not easily absorbed by patients who are cold or who have low blood pressure and are in shock. If these conditions are present, the morphine should be administered intravenously to assure immediate relief of pain, but overdosage must be avoided. The dosage must be recorded on the Emergency Medical tag.

c. *Wound*

(1) *Hemorrhage:* The first consideration in the local treatment of the wound should be the control of hemorrhage. Unless a large vessel has been severed, this can be done by the application of a pressure dressing. If this fails, a tourniquet must be applied. If a tourniquet is required, every precaution should be taken to guard against the dangers of resulting ischaemia of the extremity.

(a) Place the tourniquet at the lowest possible level.

(b) Attach a red tag to the tourniquet and record the time of application.

(c) Release the tourniquet and reapply it every hour. In the lower extremity it may be left in place for two hours.

(d) Evacuate the patient repidly to a point where the hemorrhage may be controlled surgically.

(2) *Chemotherapy:* Do not place sulfonamides in the wound, but start oral administration if the patient does not have an associated belly wound.

(3) Cover wound with an ample sterile dressing.

(4) Immobilize extremity in the appropriate splint.

d. *Tetanus Toxoid:* Administer 1 cubic centimeter of tetanus toxoid to any member of the United States Forces and record on Emergency Medical tag. Administer 3,000 units of anti-tetanic serum to any other patient, unless otherwise instructed.

V. *Amputations*

Amputations should not be attempted in the forward treatment stations unless the extremity is almost completely detached. Complete or incomplete traumatic amputations should be treated like other compound fractures. Control pain, shock, hemorrhage and apply sterile dressing and adequate splint.

VI. *Immobilization of Fractures*

The following splints are recommended as emergency measures for application in the field and for immobilization during initial transportation.

1. *Femur, Knee, and Proximal Half of Tibia:* Apply the Army half-ring hinged splint and foot traction strap. The shoe must not be removed. A tendency to apply too great a degree of traction must be guarded against. If too much traction is applied, there is great danger of causing severe and disabling pressure sores over the heel cord and dorsum of the foot. If the patient is detained at any station, the ankle strap should be released temporarily.

2. *Distal Half of Tibia, Ankle, and Foot:* Apply well-padded wire ladder splints in the following manner:

a. The first one should be applied posteriorly from the tip of the toes to well above the knee.

b. The second wire ladder splint should be applied like a sugar tong, extending down the outer side of the leg around the sole of the foot (crossing over the first splint) and back up the inner side of the leg.

c. Bandage the two splints together snugly.

3. *Shoulder, Humerus, and Elbow:* Bind the injured extremity to the chest wall with triangular bandages or with a Velpeau dressing made from gauze or muslin bandages. Do not use the Murray-Jones hinged ring splint, as it is painful, difficult to apply, and dangerous.

4. *Forearm:* Apply a well-padded sugar-tong wire ladder splint, supported with an arm sling.

5. *Wrist and Hand:* Apply a well-padded wire ladder splint to the volar surface of the forearm and palmar surface of the hand.

6. *Lumbar and Dorsal Spine:* Place the patient gently on a litter, in the prone position if possible.

7. *Cervical Spine:* Place a blanket (folded so that it makes a pad three inches thick) beneath the shoulders, thus permitting the head to fall backward slightly. Place folded blankets, articles of clothing, or any other convenient object on either side of the head to reduce lateral motion of the head.

SECTION B

Therapy in Army Installations (Field Hospitals, Evacuation Hospitals, Convalescent Hospitals)

I. *Strains and Sprains*

1. *Acute Strains*

Acute strains as a rule respond rapidly to rest. The most common strain is probably that of the lumbar muscles. Absolute rest until all tenderness has subsided is recommended. The patient is allowed to become ambulatory if the pain and spasm do not return; if he continues to improve, he should be transferred to the Army Convalescent Hospital. Those patients with strains which do not respond promptly to conservative therapy should be evacuated to General Hospitals for study and treatment. Patients with chronic disabling strains should be immediately evacuated to General Hospitals for study and disposition.

2. *Acute Sprains*

a. *Wrist Joint:* An injured wrist should never be treated as a sprain until fracture of the navicular has been absolutely excluded. Roentgenograms in three planes should be taken. Even if no fracture line is seen in the first roentgenograms, a clear-cut history of a fall on the outstretched hand, with tenderness in the anatomical snuff box, is usually sufficient to justify immobilization in plaster for ten days. At the end of this period, sufficient absorption will have occurred to make the fracture line visible in a re-check x-ray.

b. *Ankle and Knee Joint:* Some minimal sprains may be treated in Army installations. Patients with moderate and severe sprains should be evacuated immediately, as they cannot be returned to duty within any normal holding period. Any markedly distended joint should be aspirated under aseptic precautions. The involved joint should be immobilized in the appropriate circular plaster-of-Paris splint for evacuation.

II. *Dislocations*

Dislocations of major joints should be treated as surgical emergencies. As soon as possible after the diagnosis has been confirmed by roentgenographic examination, a closed reduction under general anaesthesia should be performed. After reduction, the joint should be immobilized in the appropriate circular plaster-of-Paris splint and the patient should be evacuated as soon as possible. If closed reduction cannot be accomplished or if, for any other reason, open reduction is indicated, the patient should be transferred as rapidly as possible to the nearest General Hospital. Open reductions should not be performed in Army installations.

III. *Simple Fractures*

Only a few of the simple fractures lend themselves to reduction by manipulation in Army installations. In fractures of the long bones, it is futile to attempt reduction by manipulation if it is known that reduction cannot be maintained by the use of a circular plaster-of-Paris splint. Fractures should be immobilized and the patient should be evacuated as soon as possible to a General Hospital where he can have definitive reduction by skeletal traction, and where he can remain until the fracture has become stable. No open reductions should be performed in Army installations.

IV. *Compound Fractures*

1. Because of the high morbidity and permanent disability which result from infection of compound

fractures, it is essential that they receive a high priority for surgery. Only by an early, thorough, and adequate débridement can infection be prevented.

2. Shock following compound fractures of the long bones is usually severe due to the great loss of blood; this is especially true of fractures of the femur and fractures of more than one of the long bones. Sufficient replacement of whole blood is essential. Although it may appear that the patient has been adequately resuscitated prior to the time of surgery, he may easily drop back into a state of shock during the time of operation. It is frequently necessary, therefore, to continue the administration of blood during the procedure.

3. Preoperative roentgenographic examination is of value in determining bone damage and providing information as to the number, size, and location of opaque materials, besides giving some information as to the degree of soft-tissue disruption which has occurred. The x-ray films should accompany the patient to the operating pavilion, so that they will be available to provide information to the surgeon both before and during the operation.

4. *Débridement:* The value of an adequate and thorough débridement cannot be overemphasized. An adequate débridement cannot be performed unless the surgeon is able to see and differentiate what is healthy and what is devitalized tissue. It is essential to avoid further insult to the wound, endangering vital structures which, although fortunate enough to have escaped the enemy shell fragment, may not escape the careless surgeon's instruments. The following principles of débridement in connection with compound fractures are therefore emphasized:

a. An adequate débridement cannot be performed under local infiltration anaesthesia.

b. Skin must be conserved. Excise only a very narrow margin. Rarely will it be necessary to excise more than one-eighth of an inch.

c. *Incision:* Every wound, with few exceptions, will require enlargement by incision, so that underlying damage can be visualized and dealt with properly. Incisions for enlargement of the wound ordinarily are made in the long axis of the extremity, but should be so placed that they will assist the surgeon in the General Hospital in performing the delayed primary wound suture.

d. *Subcutaneous Fat:* Remove all contaminated and crushed subcutaneous fat.

e. *Fascia:* Linear incision of the enveloping fascia is not sufficient to afford adequate drainage and prevent accumulation of blood and hematoma formation. It is, therefore, necessary also to incise it transversely. All crushed and devitalized fascia must be excised.

f. *Muscle:* Excise all devitalized muscle. Non-viable muscle does not contract when stimulated, or bleed when cut. Never cross-cut viable muscle bellies to provide exposure. Adequate exposure can be obtained by muscle-splitting incisions which are made parallel to the muscle fibers.

g. *Retraction:* The importance of retraction for visualization cannot be overemphasized.

h. *Irrigation:* This should be utilized to the utmost. It is realized that many times, due to actual water shortage, it will be impossible.

i. *Foreign Bodies:* All foreign bodies of any size should be removed. If adequate exposure has been provided, their removal will not present any problem. Blind probing and prolonged searches for very small metallic foreign bodies are condemned.

j. *Bone:* Do not remove bone fragments. Any obviously dirty bone fragments should be cleaned. If detached bone fragments are left *in situ* they act as a framework for new bone formation.

k. *Internal Fixation:* No internal fixation is to be performed. Reduction of fractures is not of importance at this time.

l. *Wound dressing:* Cover the wound with a dry, fine-mesh gauze dressing. In no case should the wound be packed or plugged. Place a large absorbent dressing over the entire wound and fix it in place by use of circular wraps of sheet wadding.

m. *Immobilization:* Immobilize the extremity in the appropriate circular plaster-of-Paris splint.

V. *Amputations*

1. *Indications for Amputation*

a. Complete destruction of the blood supply. This means the loss of the main artery and most of the collateral arteries.

b. Diffuse clostridial myositis.

2. *Level of Amputation:* Amputation should be performed at the lowest possible level which the nature and situation of the wound will permit.

3. *Type of Amputation:* Experience has shown that the open circular amputation is the procedure of choice in the treatment of war wounds. The guillotine amputation has not been found as satisfactory and it should not be used. The skin, muscle, bone and all tissues are divided at exactly the same level in a guillotine amputation, while in a circular amputation each tissue layer beneath the skin is allowed to retract before it is severed, so that, after amputation has been completed and traction has been applied to the skin, the stump has the appearance of a shallow inverted cone or saucer.

4. *Technique of Open Circular Amputation*

a. Prepare skin of extremity for surgical procedure.

b. Apply tourniquet.

c. Skin incision is made at the lowest possible level in circular manner down to the deep fascia. The incision may be made obliquely where indicated in an effort to conserve skin and length of extremity.

d. Allow skin to retract and next divide deep fascia at the level to which the skin had retracted.

e. Divide muscle in circular sweeps, cutting about three-fourths of an inch deep with each sweep, so that as the muscle retracts the next muscle division takes place at a slightly higher level.

f. Cut the periosteum of the bone circularly at the level to which the last muscle layer has contracted.

g. Saw the bone off cleanly at this level. Do not elevate, strip, or attempt to remove the periosteum at a level higher than the saw cut.

h. Nerves should be severed cleanly at the level of surrounding muscle division. Do not crush or ligate the nerve ends, or inject them with alcohol.

i. Hemostasis of the stump is essential. All large veins and arteries should be doubly ligated, each one separately, and extreme care should be taken not to include large amounts of muscle when ligating small vessels. After all the larger vessels have been ligated, the tourniquet should be removed and all remaining bleeders ligated.

j. Cover stump end with dry fine-mesh gauze. Do not "dust" or "frost" the stump with sulfonamide.

k. Skin traction should be applied immediately and be maintained continuously, while the patient is being evacuated and until healing takes place. There is one exception to this rule. In those cases where amputation is for clostridial myositis, skin traction should not be applied for the first twenty-four to forty-eight hours. No patient, however, should be evacuated from an Army installation until skin traction has been applied. Skin traction for transportation has been found to be most satisfactory if applied in the following manner:

(1) After the stump end has been covered with a sterile fine-mesh gauze, apply a circular role of stockinette to the stump and roll this proximally as far as possible.

(2) Paint the skin with tincture of benzoin and allow it to dry.

(3) Apply an adherent to the skin down to the cut skin edge, then unroll the stockinette down on the stump. Allow it to adhere to the skin. Then place traction on the stockinette and put more dressings inside the stockinette up against the end of the stump.

(4) While an assistant continues to apply traction on the stockinette, apply several layers of sheet wadding loosely over the stockinette which covers the stump. Then apply a circular plaster pylon with an outrigger made of a wire ladder splint. Tie the end of the stockinette to the outrigger with a short piece of elastic traction cord. Plasma tubing may be substituted if elastic traction cord is not available.

(5) The plaster pylons indicated in each instance are as follows:

(a) *Below-the-Knee Stump:* Below-the-knee-to-groin pylon, with the knee in full extension;

(b) *Thigh Stumps:* Single hip spica pylon, with the hip in neutral position;

(c) *Forearm Stumps:* Full-arm pylon with the elbow flexed at 90 degrees;

(d) *Arm or Humerus Stump:* Shoulder spica pylon with as little abduction as possible. The axilla should be well padded to avoid pressure.

5. *Consultation:* Decision for amputation should not be made without consultation with the Chief of the Surgical Service, or the Senior Surgeon present. The consultation should be noted in the patient's medical record.

6. *Psychotherapy* is of utmost importance in the rehabilitation of the amputee, and the surgeon, by a few words, can help in this program. It is important that the operating surgeon himself verbally inform every amputee of the following before the patient is evacuated from the hospital:

a. That the amputation was necessary as a life-saving procedure;

b. That it was decided upon after consultation;

c. That further surgery for revision of the stump will probably be necessary;

d. That he will be sent to a center where he will be given a limb and where there are other facilities for his rehabilitation.

7. *Disarticulation:* A disarticulation should be performed only when absolutely necessary. The stumps are difficult to handle, discharge profusely, and skin traction is most difficult to maintain. The stumps all need extensive revision and the majority of these revisions have to be performed in two stages. Disarticulation of the knee may be undertaken as an emergency measure, but should not be done routinely.

VI. *Immobilization of Fractures for Evacuation*

1. *General Principles*

a. No bandage, dressing, or adhesive tape which encircles an extremity, other than *sheet wadding*, is to be used under a plaster splint.

b. Adequately padded plasters are safer in average hands; therefore, padding should be used over all bony prominences, and sufficient sheet wadding should be over the soft parts to allow for some swelling.

c. All layers of plaster and sheet wadding encircling the affected extremity must be cut through down to the skin immediately after the application of the splint, and the splint must be slightly spread. In a large percentage of cases, swelling of the extremity will occur and, unless all layers of the plaster and sheet wadding are cut through, it will be impossible to spread the cast sufficiently to prevent extensive damage. This is a safety measure which must be strictly and universally adhered to.

d. Attention should be paid to the position of the extremity encased in plaster. Ordinarily the *foot* should be at a right angle to the leg, the *knee* should be in flexion of 10 degrees to 15 degrees, and the *hip* in flexion of 20 degrees. The *wrist* should be supported in slight dorsal flexion, and the *elbow* ordinarily at a right angle. Plaster applied to the hand should be trimmed back to the proximal palmar crease to permit full flexion of the fingers and metacarpophalangeal joints. A loop of wire or wicket of plaster should be applied to the foot of the plaster splint to protect the toes from pressure exerted by blankets. A plaster splint must never extend beyond the width of the litter.

e. A line diagram in indelible pencil should be inscribed on the circular plaster splint to indicate the approximate location of wounds and fractures. The date of injury, date and type of surgical procedure, and the name of the unit to which the patient belongs should be written on every circular plaster splint.

2. *Circular Plaster-of-Paris Splints:* Experience has shown that the best form of splint for use in immobilizing fractures for transport from Army installations to the Communication Zone is the circular plaster-of-Paris splint. The following splints are recommended for the fractures indicated:

a. *Double Hip Spica:* Any fracture involving the *hip joint, femur, knee joint,* and *proximal end of the tibia* should be immobilized in a hip spica. The spica should extend to the toes on the affected extremity and to just above the knee on the unaffected extremity. Abduction at the hips must not exceed that which would cause the extremities to spread beyond the width of the litter. A strut should be placed posteriorly to anchor the thigh sections together and to furnish strength. This should be placed as far distally as possible so that a bed pan can be used. The body portion of the spica need not extend higher than the rib margin. A folded bath towel should be placed over the abdomen during application of the splint, and removed when the splint is completed, so that there will be room for some abdominal distention. The posterior portion should be trimmed adequately to allow for bowel movements. A patient with *fracture of the pelvis* will be most comfortable in a full-length double hip spica. The Army hinged half-ring splint should be used only as an emergency measure and should not be used for transportation of patients from the Army installation to the General Hospital. If it is necessary, because of the tactical situation, to use this splint for evacuation of patients from the Army Zone, *the traction strap must not be used;* adhesive plaster applied to the skin of the leg should be substituted for the traction strap to provide maintenance of traction.

b. *Toe-to-Groin Circular Plaster Splint:* All fractures of the *lower half of the tibia,* of the *fibula,* and of the *ankle joint* should be immobilized in a toe-to-groin splint. A toe-to-groin cast should extend up to within an inch of the groin. However, this type of splint is not sufficient immobilization for *fractures involving the knee joint* and the *proximal end of the tibia.*

c. *Toe-to-Knee Circular Plaster Splint:* All fractures of the fore part of the foot should be immobilized in a toe-to-knee splint. The plaster should extend up to a point approximately two inches from the knee joint. *Mid-calf plaster boots are very uncomfortable and should never be applied.*

d. *Plaster-of-Paris Velpeau Bandage:* Patients with fractures of the scapula, shoulder joint, and the proximal two thirds of the humerus, travel very comfortably in this type of splint. Adequate padding about the elbow and over the bony prominences of the shoulder is essential. Care should be taken not to bind the arm too tightly to the chest. However, the splint is not comfortable if the patient is expected to be ambulatory. It is not an adequate splint for fractures in the distal third of the humerus, and those involving the elbow joint.

e. *Shoulder Spica Splint:* This is the best immobilization for all fractures of the shoulder joint, humerus, and elbow joint. It should be applied with the arm held forward and internally rotated, so that the forearm rests in front of the body and slightly below the level of the nipple line. The medial epicondyle of the humerus must be adequately and carefully padded. The elbow should be flexed to or slightly beyond 90 degrees.

f. *Circular Arm Plaster Splint:* All fractures of the *radius, ulna,* and *wrist joint* should be immobilized in a circular arm splint. The splint should extend from the proximal palmar crease to within an inch of the axillary folds, with the elbow in flexion of 90 degrees. The forearm should be in slight pronation. A circular arm splint applied for transportation should not be employed as a hanging cast for fractures of the humerus.

g. *Anterior Molded Plaster Splints:* Fractures of the metacarpals and phalanges are best splinted for transportation by the use of an anterior molded plaster splint, with the hand and fingers in a position of function, — the wrist slightly dorsiflexed, and the fingers flexed approximately 30 degrees to 40 degrees at all joints, the thumb adducted and slightly flexed. Only those fingers involved should be immobilized.

h. *Body Jacket:* Compression fractures of the vertebrae in which the spinal cord is not involved, or in which there are no accompanying fractures of the laminae or pedicles, should be reduced by hyperextension, and a plaster-of-Paris jacket applied with the patient in this position. For fractures of the lumbar or lower thoracic vertebrae, the jacket should extend from the symphysis pubis to the sternal notch. Cervical and

upper thoracic spine fractures will require an extension of the jacket to include the head. If there are fractures of the pedicles or laminae without involvement of the spinal cord, manipulation or hyperextension must not be performed, and the spine should be immobilized in a plaster jacket in neutral position. Plaster-of-Paris jackets should not be applied in cases of paralysis caused by gunshot wounds of the spine unless the stability of the spine has been destroyed.

3. The following forms of immobilization will not be used:
   a. Any form of internal fixation.
   b. Any form of skeletal fixation with wires or pins.
   c. Murray-Jones hinged ring splints for the upper extremity.
   d. Unpadded splints.
   e. Unsplit circular plaster splints.
   f. "Pulp" or finger-nail traction.

VII. *Treatment of Joint Wounds*

The following principles will be followed in the treatment of battle wounds involving joints.

1. All joint wounds must be debrided thoroughly.
2. A bloodless field should be obtained by the use of a tourniquet whenever possible.
3. Where adequate exposure cannot be obtained by enlargement of the wound, it should be assured by use of a standard arthrotomy approach.
4. All foreign bodies, loose fragments of bone and cartilage, including damaged intra-articular cartilages, must be removed.
5. All small debris and blood must be removed by thorough irrigation of the joint with normal saline solution.
6. The synovium and joint capsule should be closed with a single layer of interrupted non-absorbable sutures. (Sometimes it will be necessary to close defects in the capsule by swinging a fascial flap from the outermost layer of the capsule.)
7. If the patella has been badly shattered it should be excised, and the quadriceps and patella tendons sutured together with interrupted non-absorbable sutures.
8. After the joint capsule has been closed, aspirate the joint and inject 10,000 units of penicillin in 5 cubic centimeters of distilled sterile water.
9. Do not close the skin wound.
10. Do not place sulfonamides into the joint.
11. Do not leave drains in the joint cavity.
12. Arthrotomies should not be performed for recovery of very small metallic foreign bodies; in the majority of instances they would not be found. In these cases, aspirate the joint and inject 10,000 units of penicillin.
13. Immobilize the joint by use of the appropriate circular plaster-of-Paris splint.
14. Aspiration of the joint and re-injection of penicillin should be carried out at the end of twenty-four to forty-eight hours, or as may be indicated in each individual case.
15. The skin wound may be closed at the end of five days if no evidence of infection is present.
16. If the tactical situation permits these cases should be held for a minimum of ten days.

VIII. *Care of Hand Wounds*

The hand is an extremely useful member of the body and great disability results from its loss or its relative loss due to dysfunction. Experience in civilian and military fields has shown that early closure of wounds of the hand is essential to recovery of good function. In selected cases, primary closure may be performed in Army installations. Good surgical judgment and technique must be exercised in this procedure. Therefore, this type of work should not be relegated to the untrained and unqualified surgeon. The following instructions are guides to be followed in early surgical treatment of battle wounds of the hand.

1. *Surgical procedure:*

a. Thorough cleansing of the entire hand with soap and water is essential. This should include the clipping of the fingernails.

b. Débridement must be thorough, but should be done with meticulous care to avoid further damage. It is essential that the surgeon have an assistant. All devitalized tissues and foreign bodies must be carefully removed. Hemostasis must be complete and should be accomplished by ligation of all severed vessels with the finest ligature available (silk, cotton, or chromic catgut). Do not remove bone fragments. Only that portion of the tendon which is macerated should be excised. The suture of tendons at this time is not indicated.

c. Closure should be performed with widely placed interrupted sutures without tension. Drains should not be inserted into the wound. If it is impossible to close the wound without tension, approximate the skin edges as closely as possible with a few well-placed stay sutures. It is important that bone and tendons be covered by soft tissue wherever possible. In a few selected cases, a thin split-skin graft may be taken to cover large denuded areas.

d. *Amputation of Fingers:* Amputate only those fingers which are irretrievably destroyed. It is possible sometimes to save some skin from a finger which must be amputated; this will aid in the closing of the remainder of the hand. It is important to salvage every possible portion of the thumb.

2. *Dressings*

a. Dressings will be applied snugly but not tightly and will adequately cover the entire wound.

b. *Immobilization:* The hand will be supported on a molded anterior plaster splint, with the hand and fingers in the position of function,—that is, wrist in slight dorsiflexion, the fingers flexed approximately 30 to 40 degrees at all joints, and the thumb slightly flexed and in moderate adduction and apposition.

3. *Aftercare*

a. If primary suture of a hand is done, the patient must be held a minimum of five days for close observation.

b. The hand must be kept elevated continuously during this period to minimize swelling and oedema.

c. Penicillin is to be administered throughout the entire period.

d. The primary dressing should not be disturbed until the fifth day, unless there is evidence of sepsis. If fever or increase of pain occurs, the wound should be inspected; and, if infection is present, enough sutures should be removed to allow adequate drainage.

e. Change dressing on the fifth day and inspect the wound under aseptic conditions. This is to avoid placing in the chain of evacuation the occasional patient who may have a low-grade infection without clinical manifestations.

f. Instruct the patient to keep the hand in a position of elevation during his evacuation.

IX. *Gas Gangrene*

1. *Types of Wound:* Wounds destroying muscle, either directly or by interruption of the blood supply, are particularly susceptible to anaerobic or clostridial infections.

2. *Types of Infection:* The following types of infection must be recognized, since they require different methods of treatment.

a. *Clostridial Gas Gangrene*

(1) Diffuse myositis;

(2) Localized myositis;

(3) Cellulitis or "gas abscess".

b. *Streptococcal Gas Gangrene* (rare): Myositis.

3. *Diagnosis*

a. *Clinical:* Differential diagnosis of the various types of clostridial gas gangrene and streptococcal myositis must be made to avoid unnecessary or radical surgical treatment.

(1) *Clostridial myositis, diffuse:* This may develop within six hours from the time the wound was received and usually develops within three days. The onset is acute, with a severe systemic reaction. Locally there is *pain, marked swelling,* frequently profuse serous *exudate, slight gas formation, variable odor of decay,* and pale or blue-gray appearance of the involved muscle. The skin is tense and often white, but may be mottled with a livid appearance if the process is widespread.

(2) *Clostridial myositis, localized:* Symptoms and signs are the same as for the diffuse type except that the process is restricted to a single muscle or group of muscles.

(3) *Clostridial cellulitis:* This process is limited to the immediate area of the wound. The onset is gradual, usually three days after injury, with slight systemic reaction. Locally there is abundant gas formation with a foul odor and slight swelling, and little local change of the muscle and overlying skin is present.

(4) *Streptococcal myositis:* The onset is delayed for three or four days, and severe systemic reactions do not appear until the late stages of infection. Locally, there is *marked swelling, with profuse purulent discharge, slight gas formation, and slight odor.* The involved muscle is slightly oedematous and the overlying skin is *tense,* often with a coppery tinge. Streptococcal myositis comprises only a few of the cases of gas gangrene.

b. *Laboratory Evidence:* Recognition of the infections mentioned must be made on the basis of clinical findings because adequate laboratory facilities are not usually immediately available. Confirmatory laboratory evidence is of statistical importance only and should be obtained when possible, but should not influence the treatment.

c. *Roentgenographic Evidence:* The mere presence of gas shadows in a roentgenogram is not sufficient evidence of gas gangrene infection.

4. *Prophylaxis:* Early adequate débridement of wounds is the best prophylaxis for anaerobic infections. Débridement in cases where there has been massive destruction of tissue, more particularly in the region of the perineum and the proximal portion of the femora, and in cases where major vessels are injured, must be radical and thorough, and long incisions must be made.

5. *Treatment*

a. *Surgical:* This depends upon the extent of the disease and the type of anaerobic infection.

(1) *Clostridial myositis, diffuse:* Amputation well above the site of involvement *must be carried out immediately,* using the circular method, and leaving the wound open. Do not apply skin traction for forty-eight hours.

(2) *Clostridial myositis, localized:* Extirpation of the involved muscle, or group of muscles, is indicated.

(3) *Clostridial cellulitis:* Incise the localized area and remove the devitalized tissue. Radical surgery is not indicated.

(4) *Streptococcal myositis:* Extensively incise and drain the involved muscles. Radical extirpation or immediate amputation are not indicated.

b. *Serum Therapy*

(1) Gas-gangrene antitoxin is only effective in combatting the toxin. Its use is not indicated in those cases in which toxic manifestations are not present. When indicated, it should be administered intravenously and the dosage should be governed by the degree of toxicity manifested. Precaution should be taken to guard against allergic reaction, both *early* and *delayed.*

c. *Antibiotics and Chemotherapy:* None of the sulfonamides nor the various antibiotic agents have any specific action against clostridial infection, but they may be used parenterally or by mouth to help control other bacteria present in these wounds. In the European Theatre in 1944 and 1945, when only penicillin and sulfonamides were available, the following routine was used:

(1) *Penicillin:* Give an initial dose of 20,000 units intravenously and 20,000 units intramuscularly, followed by 20,000 units intramuscularly every two hours for a period of three days. Period of therapy may be modified as necessary.

(2) *Sulfonamides:* Give 6 grams of sulfadiazine by mouth initially and 1 gram every four hours thereafter.

d. X-ray irradiation is not indicated.

e. Supportive treatment: Since there is a rapid destruction of erythrocytes, frequent whole-blood transfusions will be necessary.

f. All instruments used in cases of anaerobic infections should be sterilized by autoclaving, whenever possible. The instruments must not be covered with oil, since bacteria surrounded by oil are protected against moisture and therefore are not killed at the usual temperature.

g. If gas-gangrene antitoxin is used, record the number of ampules used and the name of manufacturer.

X. *Vascular Injuries*

All patients whose extremities are affected and who have had injuries or ligatures of major arteries should be held in Army hospital installations for treatment and observation until the danger of either circulatory or gas gangrene is past. In most cases, this time interval is approximately ten days. If either gas or circulatory gangrene develops, amputation and other indicated procedures should be carried out before the patient is evacuated.

Patients with a damaged popliteal artery and exhibiting a cold extremity, with hard muscles and loss of sensation distal to the lesion, should have a transcondylar amputation as a primary procedure.

SECTION C

Therapy in Communication Zone Installations (General Hospitals and Station Hospitals)

I. *Strains and Sprains*

1. *Strains:* Those strains which do not recover rapidly with conservative treatment should be studied thoroughly for a definite diagnosis or to establish the cause of continued symptoms.

2. *Sprains*

a. *Ankle joint:* Severe sprains lead to partial permanent disability if they are not properly diagnosed and treated early. The possibility of diastasis of the inferior tibiofibular joint and rupture of the collateral ligaments must be considered.

b. *Knee joint:* A differential diagnosis of the pathological findings in the joint must be made. Treatment and disposition will depend upon the evacuation policy. If the patient has a sprain of the knee, he may be returned to duty within six weeks. If the injury is more serious, such as an internal derangement, the period required for recovery and return to full duty will be four to six months. Many will never be able to return to full duty. No purely *exploratory arthrotomy* of the knee joint will be performed.

II. *Dislocations:* Ordinarily reduction will be performed by manipulation under general anaesthesia. Open reduction may be resorted to, after adequate consultation, when closed reduction has failed.

III. *Simple Fractures:* Fractures of the long bones should be treated by skeletal traction. Open reduction is not to be performed routinely, but only after an adequate trial of reduction by skeletal traction has failed. After these fractures have become stable, they should be placed in the appropriate circular plaster-of-Paris

splint and the patients will be evacuated to the Zone of the Interior. Double pin and plaster fixation is not to be used. Badly displaced fractures of the radius and ulna which cannot be reduced by other means may be treated by open reduction and internal fixation.

Fractures of the metatarsals and phalanges should not be immobilized for long periods of time in plaster casts. "Pulp" traction should not be used.

IV. *Compound Fractures*

1. *Delayed Primary Wound Closure:* This is the greatest single advance in the treatment of compound fractures due to battle wounds. Experience has shown that it is desirable to close these wounds as early as possible after the patient arrives in the General Hospital. This should be performed at the time of the first wound dressing, providing the wound is clean and there is no gross evidence of infection. If infection is present, it should be treated; and, as soon as the infection has been controlled, the wound may be closed. Some wounds may require secondary débridement to control or eliminate infection before they are ready for delayed primary closures. If the closure is done within the first ten days, the skin edges are usually still mobile and may be readily approximated with widely spaced and deeply placed non-absorbable sutures without undue tension. Where wounds cannot be closed without tension because of loss of skin, the closure should be completed with skin grafts. If the wound is ten days old or older, it will usually be necessary to excise the new epithelium at the margin of the wound and undercut the skin edges to make them mobile so that they may be approximated. Penicillin or other antibiotics parenterally or by mouth should be administered one day prior to and several days after the operation. Sulfonamides should *not* be placed in the wound.

2. *Reduction and Immobilization*

a. *Fractures of the Long Bones:* Fractures of the femur, tibia and fibula, and of the humerus will be treated by skeletal traction in every instance where it is possible to achieve a beneficial result within a reasonable length of time. Skeletal traction will be maintained until the position of the fragments has become sufficiently stable so that they will not displace or angulate during transportation in a circular plaster-of-Paris splint. The average periods during which patients with these fractures were held in the European Theatre of Operations are as follows:

Femur	9 to 12 weeks
Tibia and fibula	5 to 7 weeks
Humerus	4 to 6 weeks

b. *Fractures of the Long Bones with Loss of Bone Substance:* Those patients who have had large loss of bone substance should not be placed in skeletal traction. The part affected should be allowed to shorten so that there will be bone contact. This method is far from ideal. Alignment should be maintained by plaster immobilization and every effort made to effect an early primary closure of the wound. These patients need not be held until the fracture becomes stable, but should be returned to the Zone of the Interior at an early date in the appropriate circular plaster-of-Paris splint.

c. *Fractures of the Long Bones with Severe Nerve Paralysis:* In these patients, the nerve injury takes precedence; therefore, they should immediately be transferred to a neurosurgical center where they will be handled in the following manner:

Do not overcome shortening by application of skeletal traction as it may defeat the possibility of accomplishing an end-to-end suture of the nerve. Splint the fracture in good alignment and perform a primary delayed wound closure at the earliest possible date. If closure is successful and there is no evidence of residual infection at the end of three weeks from time of closure, a combined operation should be done, suturing the nerve end to end, performing open reduction of the fracture and using internal fixation when indicated.

d. *Internal Fixation in Compound Fractures:* Internal fixation of compound fractures is prohibited as a routine procedure. It should be resorted to only after a thorough trial of skeletal traction has failed to secure adequate reduction, and after healing of the compound wound has been accomplished by suture or skin graft.

e. *Fractures of Forearm:* These may be treated by circular plaster splints or by skeletal traction when feasible. Badly displaced fractures may require open reduction with internal fixation if other methods have failed. This will not be performed until three weeks after a successful delayed primary closure of the compound wound.

f. *Fractures of the Hand and Fingers:* In no case should they be immobilized for more than two weeks (see Care of Hand Injuries, VIII).

g. *Fractures of the Foot:* The primary consideration should be the healing of the wounds through treatment by suture or skin grafting, followed by early active motion of toes and tarsal joints.

h. *Steinmann Pins and Plaster, Anatomical Splint:* The use of double Steinmann pin with plaster-of-Paris fixation and external metallic fixation splints is not to be permitted as a routine procedure. This method of reduction and immobilization has led to gross infection and ulceration about the pin wounds in a high percentage of cases.

V. *Amputations:* The same principles for amputation as are outlined in Section B will also be followed in General Hospitals. All amputations performed are to be done by the open circular technique. (In cases where

traumatic amputations were followed by amputations done in the forward areas, the stumps showed irregular skin edges.) In most instances, skin traction will effect closure if it is adequately applied and maintained. Secondary closure of these stumps will not be performed in this Theatre. If the skin sleeve is inadequate for closure by traction, or if the bone ends are obviously too long, revision of the stump should be performed. The skin edges should be mobilized by undercutting. The protruding muscle and bone should be re-amputated just sufficiently to allow closure by continuous skin traction. Split-thickness skin grafts on stumps of the lower extremity will not tolerate a prosthesis. The use of such grafts to cover amputation stumps is prohibited unless there is an unusual indication. Skin traction should be maintained continuously. As soon as possible after an amputation case is admitted to a General Hospital, the temporary pylon splint and skin traction should be removed and replaced. In the General Hospital traction is best applied by use of weights and pulleys attached to the bed. The traction apparatus should be arranged so that in thigh and leg stumps a greater degree of skin traction is exerted on the posterior portion of the stump. Patients with amputations should be in a condition to be evacuated to the Zone of the Interior two or three weeks after admission to a General Hospital. Stumps do not have to be completely healed. However, skin traction is to be maintained during evacuation by the reapplication of the plaster splint pylon with outrigger as described in Section B.

VI. *Splinting of Fractures for Transfer to the Zone of the Interior*

The same general principles (Section B, VI) will be followed in the application of circular plaster-of-Paris splints for evacuation to the Zone of the Interior, with the exception that these are secondary plaster-of-Paris splints applied weeks after the injury or operation and therefore *need not be split.* All patients should have new plasters applied just prior to departure.

VII. *Joint Wounds:* These wounds should be closed at the earliest possible moment by suture or skin graft. If the joint surfaces are not badly damaged, early active motion should be insisted upon. If, however, the joint surfaces are so badly damaged that ankylosis is inevitable, the various joints should be immobilized in the best position for function. The following positions are recommended.

1. *Hip Joint:* Flexion of 25 degrees and abduction of 5 degrees, and neutral position without medial or lateral rotation.
2. *Knee Joint:* Flexion of 10 to 15 degrees.
3. *Ankle Joint:* Foot, 10 degrees less than right angle for males; 20 degrees less than right angle for females.
4. *Shoulder Joint:* Abduction of humerus of 65 degrees, 45 degrees forward of the transverse body axis, and in mid-rotation. This position enables the patient to reach his face with his hand.
5. *Elbow Joint:* Flexion of 90 degrees. In bilateral cases immobilize the more seriously damaged joint at 90 degrees and the other at 130 degrees.
6. *Wrist Joint:* Dorsiflexion of 40 degrees without radial or ulnar deviation.

VIII. *Hand Injuries:*

Centers have been established to care for hand injuries, as these present special problems. Those hand wounds which have not had a primary closure in hospitals in the forward areas should be closed by delayed primary closure or with skin grafts as early as possible. The danger of prolonged immobilization of the hand and fingers cannot be overemphasized. A useful hand with imperfect bone alignment is far more desirable than a stiff hand with perfectly reduced fractures. In selected cases, skeletal traction may be used, but every effort should be made to maintain active motion of the uninvolved fingers. Such traction should not be employed longer than two or three weeks. In no instance should "pulp" traction be used. Amputations should be performed early if there is no possibility of restoring some useful function. Whenever possible, any portion of the thumb should be saved. Effective active exercises under the supervision of a physical therapist must be instituted early and pursued with diligence.

IX. *Gas Gangrene:* Same principles of treatment apply as outlined in Section B, IX.

X. *Vascular Injuries:* These are not considered to be orthopaedic problems except for those cases which require amputation, and those which require treatment of an associated fracture.

XI. *Elective Orthopaedic Surgical Procedures:* It must be borne in mind that any major procedure of this kind requires a relatively long period of convalescence and that there are few which will result in complete elimination of a partial permanent disability. As a rule patients requiring the following procedures will be transferred to the Zone of the Interior:

1. Arthrodesis of the spine or of any major joint;
2. Bone grafts for non-union;
3. Any type of operation for recurrent dislocation of the shoulder;
4. Arthroplasties, including bunion and hammer-toe operations;
5. Arthrotomies for correction of internal derangement of the knee joint.

Certain exceptions may be made for the possible salvaging of key personnel. In such cases the concurrence of the local orthopaedic or surgical consultant will be secured before such a procedure is carried out.

ORTHOPAEDIC SURGERY IN YUGOSLAVIA

BY HENRY H. KESSLER, M.D.,* NEWARK, NEW JERSEY

Five hundred thousand men, women, and children, victims of war, disease, accidental injuries, and congenital deformities, require rehabilitation services in Yugoslavia. This problem is so formidable that it cannot be solved without international support and action. The Technical Assistance Administration of the United Nations had been asked by the Government of Yugoslavia to furnish help and counsel in meeting this problem. The first step in providing this assistance was a survey of the needs.

Health Problems

Despite the many problems facing Yugoslavia today, no one can visit this country without immediately sensing a ferment and élan which has probably been carried over from the war of liberation. Behind the élan one finds the face of hunger and the ravages of war and disease—Yugoslavia's legacy from centuries of invasions and a low standard of living. This is reflected in the country's high incidence of disease and the invalidism which accompanies it.

War Injuries

One million, seven hundred thousand persons, 10 per cent. of the population, were killed in the War. This number, together with the 80,000 disabled veterans, points to the fury of the war. It indicates also the lack of medical facilities, which forced the addition to the mortality lists of many who could have been saved by appropriate measures.

A broad and comprehensive program of medical care, hospitalization, pensions, vocational training, and resettlement in economic enterprises has absorbed these 80,000 persons; and this program serves as an excellent example for a similar rehabilitation effort for the civilian disabled.

Not included in this group of disabled war veterans are the large numbers of children mutilated by mines and unexploded bombs, as well as substantial numbers in the upper age levels, victims of the Balkan wars which have characterized the history of these countries for many generations.

Accidental Injuries

Despite the lack of automobiles in Yugoslavia, the number of street accidents has risen to a formidable degree. The main problem is that of industrial accidents. The rapid program of industrialization has gone forward faster than the training and conditioning of new workers.

Disease

The most important health problems are contagious diseases, the need for public-health education, and for maternity and child health and welfare work. The whole country has inherited a legacy of disease, the remains of a series of typhus and malaria epidemics. Until 1947, there were 347,000 cases of malaria a year. At one time malaria was so widespread in Macedonia that crops had to be left unharvested. Trains could not leave the station because the crews were so ill. Today, since the introduction of D. D. T., malaria is but a bad memory. Typhus, too, seems to be well controlled, although the very day that the United Nations group visited Skoplje, a case had appeared in a blind "collective", necessitating the vaccination of everyone in the "collective".

Of all the contagious diseases, tuberculosis, in both pulmonary and extrapulmonary forms, is the most difficult problem. More than 20,000 cases have been registered, but the actual number of unregistered and concealed cases may be inferred from the special studies of Neubauer, who found 2 per cent. of one segment of the population with active pulmonary tuberculosis. This ratio, applied to the population of 16,000,000, would represent a total number of 320,000 cases.

Congenital Deformity

Yugoslavia shares with many Continental countries a high incidence of congenital deformity. Here, as in Czechoslovakia, the incidence of congenital dislocation of the hip has been estimated at 2 per 1,000 children, compared to 3 per 1,000 in France and Italy.

Summary

To summarize, these are the major orthopaedic problems in the four categories listed above: (1) war injuries—amputations, chronic osteomyelitis, and peripheral-nerve injuries; (2) accidental injuries—mostly acute cases, but some residual fracture deformities exist; (3) disease—manifested by a high incidence of bone

* Dr. Kessler has just returned from a six weeks' survey of Yugoslavia as a consultant for the Technica Assistance Administration of the United Nations.

and joint tuberculosis, referred to as OAT (osteo-articular tuberculosis), and a small number of deformities due to poliomyelitis; (4) congenital deformities—consisting chiefly of congenital dislocation of the hip, club-foot, and cerebral palsy.

Medical Services

Governmental Organization

Yugoslavia is a federation of republics: Serbia, Croatia, Slovenia, Bosnia-Hercegovina, Macedonia, and Montenegro. Each republic has a Ministry of Health responsible for all medical and health matters. A Ministry of Social Affairs shares with the Ministry of Health joint responsibility in the matter of industrial accidents. In the control of the problems of crippled children and war disabled, and in the establishment of homes and centers for the blind and deaf, the Ministry of Social Affairs assumes responsibility alone.

A Federal Committee of Health coordinates the health activities of all the ministries of the republics and, acting in concert with them, prepares legislation and statistics and carries out over-all supervision and control. Although this control is fairly well centralized, close cooperation and collaboration with the local medical society is practised. Even in so simple a matter as preparation of a traumatological conference, the planning is conducted in conjunction with the wishes of the medical association.

Personnel

The great problem is the shortage of doctors. Fifteen hundred doctors were lost in the War; 50 per cent. of the remaining 6,000 physicians are over fifty years of age. Sixteen thousand doctors are needed to meet the medical and public-health needs of the country.

To meet these needs an ambitious program of medical education is now under way. Eight thousand medical students are in training, while new medical schools have been established in Macedonia and Bosnia, and the two-year course in Ljubljana has been expanded to a full six years.

The standards of medical practice are high, and specialized training, including training for orthopaedic surgery, requires four years beyond the regular medical course. There are ten qualified orthopaedic surgeons in Zagreb, eight in Belgrade, three in Ljubljana, one in Kraljevica, one in Rijeka, and two in Rovin. There are none in Macedonia or Bosnia.

The training of allied medical personnel, such as nurses, nurses' aides, laboratory technicians, x-ray technicians, and physical therapists, is also being carried out at a feverish rate.

From 1918 to 1941 only 1,253 allied medical personnel were trained; in 1949, 1,750 persons received this training. Two physical-therapy schools have been established, one in Zagreb and the other in Ljubljana.

Hospitals

The total number of hospital beds in the entire country is about 55,000. Only 1,100 are available for patients with bone and joint tuberculosis. There are only four homes for crippled children in the entire country, and these are of very small capacity. Because of the high accident rate, special traumatological institutes have been established in several of the large cities. There are no rehabilitation centers, although during the War a large military rehabilitation center existed near Zagreb. A few homes for war invalids still remain.

An excellent feature is the presence of well equipped and satisfactorily operated orthopaedic workshops for the manufacture of artificial limbs, braces, appliances, and orthopaedic shoes.

Belgrade

Orthopaedic activities in Belgrade are carried out with the limited facilities of the children's clinic and the state hospital.

Children's Clinic

Of the 260 beds at the children's clinic, 110 are available to the surgical service, which is headed by Prof. Jovcic. He is a pupil of Prof. Ombrédanne in Paris and, like him, carries out the entire gamut of children's surgery, including general surgery, plastic surgery, neurosurgery, and orthopaedic surgery. While the majority of orthopaedic cases are those of bone and joint tuberculosis, accidental injuries and congenital dislocations of the hip are next in frequency.

In the past five years, there have been more than 7,000 injuries to children. This number includes 2,211 fractures as well as many cases of burns which are referred here for treatment by skin-grafting. During 1945 and 1946, fifteen children a day were admitted because of mutilation by land mines.

The incidence of poliomyelitis is relatively low, and fortunately the disease has not appeared in epidemic form. Similarly, cerebral palsy has not been a great problem.

Echinococcus disease occurs in many forms and places, involving various parts of the body including the lungs and liver. In one case, the body of the vertebra was involved, resulting in paraplegia which was subsequently cured by laminectomy.

Prof. Jovcic is especially interested in the Förster operation for spastic paralysis and presented several cases with satisfactory, if not marked, improvement in the spasticity following operation. He has also carried

out the Zahradníček operation in many old unreduced dislocations of the hips. In this operation, the shaft of the femur in the sub-trochanteric area is resected sufficiently to bring the head down and into the acetabulum. The fragments are then secured with a Küntscher nail. Of the cases seen, the reductions were excellent, but severe stiffness of the hip remained.

State Hospital

The orthopaedic department at the state hospital, *Derstava Bolnica*, a three-story structure with 150 beds, is supervised by Prof. Zeta Stojanovic. The majority of cases seen are of bone tuberculosis, of which Prof. Stojanovic has treated 2,500. The results of streptomycin treatment in children have been good in 95 per cent. of the cases, but the treatment in adults has not been satisfactory except in cases with sinus. The order of incidence of orthopaedic conditions in this institution is as follows: (1) tuberculosis; (2) fractures (3,500 in children); (3) osteomyelitis; (4) congenital dislocation of the hip; (5) osteo-arthritis; and (6) poliomyelitis.

Plastic-Surgery Unit

Housed in a 100-bed former private hospital is a modern plastic-surgery unit under the supervision of Dr. Arneri of the Military Hospital. Since 1945 four British plastic-surgery teams have provided training for Yugoslavic surgeons and their nursing staffs. The mutilations of war are now giving way to the injuries and defects of civil life. An empty place where a nose might have been and a few reminders of the grim war in a blind veteran with amputation of both upper extremities, with extensive facial wounds, noma, lupus, bites of mice, and scars from burns, make up the list of severe deformities that require treatment.

Traumatological Institute

The gradual increase in accidental injuries has focused the attention of the health ministry upon this problem. The ministry has responded with the creation of traumatological institutes or emergency hospitals with special equipment and specially trained personnel. A former sixty-bed private hospital has been converted into such a traumatological institute, providing complete and adequate treatment for emergencies. Patients remain until their wounds and fractures have healed. Rehabilitation of these accident patients is also a definite concern of the various authorities, and plans are now in progress for the establishment of rehabilitation centers to meet this need. In the meantime, rehabilitation services are being improvised by the inclusion of remedial gymnastics in the small physical-therapy department. In order to provide this service, it was necessary to equip the waiting room as a gymnasium, since no other space was available.

Orthopaedic Workshop

One of the outstanding achievements has been the establishment of orthopaedic workshops for the manufacture of artificial limbs, braces, and orthopaedic shoes. Limbs are largely of linden wood, with leather and steel. Braces are made according to the Hessing system, with long thigh and leg cuffs. Orthopaedic shoes are well constructed and of high quality.

The shop seen by the writer covers almost five acres, employs 230 men, with fifty-eight in the limb-fabrication department, and five well trained limb fitters, several of whom have had graduate training in France, Sweden, and England. In addition to these workers, a limb-fitting surgeon supervises the dispensing and fitting of all appliances.

Macedonia

Macedonia has emerged from centuries of oppression, Turkish rule, and illiteracy into the light of modern civilization and responsibilities. However, it is still burdened with archaic folkways and traditions. In the ninth and tenth centuries, Macedonia had its own art, literature, and culture. Successive invasions almost obliterated it as a cultural unit.

Today it has its own schools, literature, and newspapers. Despite the long years of suppression, Macedonia exhibits a fierce will to wipe out its centuries-old backwardness in a comparatively short time. Illiteracy is gradually being abolished. Nevertheless, living conditions are still primitive, and the menace of contagious disease constantly threatens. Tuberculosis takes its toll in ever-increasing numbers, both in the pulmonary form and in the form of osteo-articular tuberculosis.

Although medical facilities are still inadequate, considerable progress has been made in the short space of three and a half years. Here as elsewhere there is a very evident shortage of physicians, with only 200 doctors in the whole of Macedonia, an average of one doctor per 10,000 population. There are about seventeen hospitals in the republic, with a total of 2,500 beds, compared to 800 beds available before the War. A new medical school has been established at Skoplje, with an enrollment of 500 medical students. With all its physical limitations, the university has an energetic and well-qualified faculty who inspire the students with their zeal.

Medical activities for the most part are centered in the university hospital of 800 beds. At the head of the staff is energetic Prof. Jubasic, trained with Prof. Schmieden of Frankfort. He conducts a general surgical

service of 200 beds, with an efficiency of organization and a technical competence that would compare favorably with surgical clinics in London, Paris, or New York. Unfortunately, there is no orthopaedic service, although one member of the staff has recently been selected for training in orthopaedics. The lack of beds has made it necessary to limit admissions to acute surgical cases, so that long-term orthopaedic cases are given little consideration. Fractures are treated by the surgical service and in many cases the Küntscher nailing has been carried out. A few cases of bone and joint tuberculosis have been treated here, some by Calot's method of injection into the cold abscess, as no streptomycin was available. Many of the patients with bone and joint tuberculosis had to be treated in the out-patient department, and they frequently brought their plaster beds with them. The tuberculosis situation is so serious that plans have been completed for the establishment of an eighty-bed sanatorium at Ochrid Lake.

Skoplje will not be denied its place in general medical progress. The fact that there is no orthopaedic department at the university and no orthopaedic surgeon in Macedonia has not deterred its physicians from establishing an orthopaedic workshop, located in the old Turkish quarter of the town. The "*Meister*" is only twenty-five years old, but he already displays a confidence and a technical knowledge far beyond his years. The shop was opened in March 1950, and already eighty limbs and many braces have been completed.

Another unusual project is a large, well equipped out-patient physical-therapy department in the large polyclinic or dispensary, located near the center of the city. A wide variety of treatments is offered, including a hydrotherapy department which unfortunately cannot yet be used because of the lack of hot water. The department is supervised by two specially-trained physicians, but trained technicians are few.

An orthopaedic clinic is held at the University and University Hospital, where the writer found a wide variety of cases, including many cases of poliomyelitis, congenital dislocation of the hip, tuberculosis, and many amputees.

Bosnia—Hercegovina

Bosnia and Hercegovina together have a population of 2,000,000, half of them Moslems. This republic is the center of the newly developed heavy industries, with coal, iron, chemical, and textile industries predominating. It is called the Yugoslav Ruhr. Sarajevo, the chief city, noted as the starting place of World War I, has a population of 140,000. In all of Bosnia there are only 370 physicians, or one for every 7,000 persons. Fifty per cent of the doctors are in Sarajevo.

Despite the legacy of feudalism, which existed in Bosnia until 1918, of an illiteracy rate of 85 per cent., of centuries of living in filth, of the destruction of 100,000 homes, of looting and vandalism, and of many dead and invalided, Bosnia has approached a new economic and social era.

A medical school was established in Sarajevo in 1947, with an enrollment of 800 students. A vast program of expansion of public-health facilities is in progress. The dean of the medical school is Dr. Nedo Zec, a neuropsychiatrist trained by Wagner-Juaregg in Vienna and formerly Minister of Health of Bosnia.

University Clinic

The center of all medical and surgical activities is the University Clinic, situated on a hill overlooking the neighboring mountains. Built by the Austrians in 1895, in large, roomy fashion, it has served as a general hospital. There are 1,500 beds, with about 300 beds devoted to surgical cases.

Prof. Kovacic, a Montenegran trained in Vienna and Paris, demonstrated in two days of operative surgery a great technical skill and a great versatility in the management of a wide variety of surgical conditions and specialties. There is no special orthopaedic service, although a special traumatological service is contemplated because of the increasing number of accidents. Prof. Kovacic at present supervises all traumatological cases, including those with involvement of the extremities. Orthopaedic cases, because of their chronic character, are necessarily deferred to make room for the acute surgical cases. Included in the gamut of general surgery are a large number of cases of acute osteomyelitis in children. In such cases, radical treatment by complete diaphysectomy, especially of the tibia, has been carried out here for the past three years, with encouraging results.

Because of the writer's own interest in Krukenberg and cineplastic procedures, Prof. Kovacic demonstrated an excellent case of bilateral Krukenberg stump in an amputee who is now employed as a staff aide in the hospital.

Research in Endemic Syphilis

One of the most remarkable public-health projects has been the program for the detection and treatment of endemic syphilis. Under the supervision of Dr. Ernest Green, 400,000 persons have been examined in a house-to-house, village-to-village canvas. Three mobile laboratory units have been planned for a systematic blood examination for the entire population of Bosnia. This is to be followed by penicillin treatment in positive cases. More than 10 per cent. of the population was found to be infected, and of this number (40,000 cases) 20 to 30 per cent. show bone and joint involvement. The incidence in a selected group of cases is as follows: arthralgia, 60; osteitis, 54; hydrarthrosis, 35; tumor albus, 11; osteo-arthritis, 10; spondylitis, 10. These bone manifestations of the disease do not respond well to treatment.

Orthopaedic Workshop

On the outskirts of Sarajevo is a well equipped and efficiently operated limb and brace shop, originally established as a private commercial enterprise in 1919 under the old regime, apparently under the supervision and craftsmanship of German-trained personnel.

About 6,000 units are made each year, mostly braces made according to the methods used in Belgrade, with long thigh and tibial leather cuffs. Below-the-knee and above-the-knee pylons are especially popular in rural areas, but this varies considerably from place to place; the young farmer still prefers the cosmetic value of a regular shoe to the questionable ease of operation of the pylon. About thirty-five artificial hands have been made and these are used chiefly by city dwellers, whereas the villager prefers the American hook (the "miracle" hand and hook, 5,000 of which were given to Yugoslavia by the Red Cross and UNRRA).

Suction-socket limbs are made at the rate of ten a month, while the number of conventional prostheses for the lower extremities averages about thirty a month. The wooden limbs are covered with rawhide and are spray-painted. The feet are mass-produced by copying machines in Belgrade. The below-the-knee leather prostheses have soft sockets.

Dalmatia

Costa Bella Sanatorium

The beautiful Dalmatian coast, long a traditional tourist paradise, is now the site of many institutions, hotels, and rest homes where weary workers, undernourished children, and those in need of special care receive adequate attention. One of the many sanatoria for osteo-articular tuberculosis is Costa Bella. Located on the shore, not far from Rijeka, it houses 783 children in all stages of bone and joint tuberculosis.

Patients from seventeen months to fourteen years of age are accepted. They are housed in high-ceilinged rooms with access to large open terraces, where, in good weather, they can benefit from the sun and air. Education is carried out simultaneously with treatment, and children are assigned to groups according to school grade rather than types of disability.

Treatment is almost completely conservative, with plaster immobilization, some traction, and prolonged bed rest. A few children have been operated upon in the orthopaedic section of the general hospital in Rijeka. While the sanatorium for osteo-articular tuberculosis at Costa Bella is essentially an institution of the Croatian Republic, beds are assigned for cases selected by the Ministry of Health from the other republics. The average stay is about eighteen months.

Streptomycin has been a great boon; it is especially valuable in the cases with open fistulae. Since the introduction of streptomycin, fistulae have occurred in only ten per cent. of the children's cases. Before, the incidence had been about 30 per cent. Paraminosalicylic acid (PAS) has not been too well tolerated by the children.

Pott's disease predominates among the cases, yet there is relatively little paraplegia. When this does occur, treatment is carried out along conservative lines, with plaster belts and extension.

General Hospital at Rijeka

Rijeka is a city of 100,000 persons, but the large General Hospital serves the needs of the surrounding population of 700,000.

The orthopaedic department is headed by Dr. Denko Sporn, who was trained in Zagreb, originally as a general surgeon and since 1941 in orthopaedic surgery. Now aided by a woman assistant and an orderly who acts as anaesthetist, he manages to perform major orthopaedic surgery with limited instruments (there is no electric saw). He was without x-ray films for eight months, and he has only a small portable x-ray unit, with small squares of film even for large fractures. He performed 339 major orthopaedic operations without a death or infection in 1949. Dr. Sporn also has artistic ability and draws the operative procedure on the operation chart.

Here in Rijeka, in contrast to Belgrade, Skoplje, and Sarajevo, poliomyelitis is the most frequent cause for admission. Meniscus lesions of the knee, ankylosis of the hip in vicious position following tuberculosis, and congenital dislocation of the hip are, in that order, the most common conditions treated.

In the section of infectious diseases of the hospital, under the supervision of Dr. Rukovina, a large number of cases of brucellosis have been treated. Among them are many orthopaedic cases with affections of the hip simulating Perthes' disease. In brucellosis, the lesion is a subchondral necrosis of the femoral head, but, in contrast to the lesion in Perthes' disease, there is a substantial amount of secondary sclerosis. Aureomycin has been of no value in the treatment of the chronic cases.

Kraljevica Sanatorium

Kraljevica, one of the most famous of the sanatoria for osteo-articular tuberculosis, is located on the beautiful Dalmatian coast about 50 kilometers south of Rijeka. Built as an Austrian hotel in 1905, it was turned into a children's home after World War I, and into a tuberculosis sanatorium in 1924. Its reputation had been well established when, in 1930, it was given prominence in a chapter in Engel-Pirquet's *Childhood Tuberculosis*. At the present time it contains 190 beds for patients with osteo-articular tuberculosis and for

some with non-tuberculous orthopaedic conditions. Most of the patients are adults, but some children are admitted. The physician in charge is Dr. Alex Manzoni, trained in Zagreb.

Pott's disease predominates, with a few cases of paraplegia; there are also many cases of sacro-iliac tuberculosis.

Most of these patients have responded well to conservative treatment,—with prolonged bed rest, immobilization in plaster, extension, and streptomycin. The hospitalization period is prolonged; very little surgery is performed. During 1950 only 100 operations were performed, and the majority were in non-tuberculous orthopaedic cases. However, further use of early surgery is being explored in the light of American, Mexican, Greek, and Philippine experiences. Vocational rehabilitation of patients is being considered, so that the period of hospitalization may be utilized to prepare the patient for a new job or to improve his skills for his former job.

Home for Crippled Children

About five kilometers south of Kraljevica is a home for crippled children called *Kraljevica Ostro*. It provides convalescent care, education, and recreation for a period of six months for thirty-eight boys and girls from five to fifteen years of age. Most of the children are victums of poliomyelitis, or have congenital dislocation of the hip; some are amputees. Many of the children show the crippling effects of injuries sustained during the War, when they acted as couriers, frequently equipped with guns to defend themselves against capture. Two of the youngsters had bilateral below-the-elbow amputations with Krukenberg stumps.

Sanatorium at Rovin

Another large sanatorium for osteo-articular tuberculosis with 415 beds for men, women, and children, is located at Rovin. About 10 per cent. of the cases treated are non-tuberculous. The physicians are Dr. Martin Horvat and his wife, both orthopaedists trained at Zagreb.

Most of the treatment is conservative, with surgery performed only after a thorough trial of conservative treatment. About 160 operations are performed a year, including the non-tuberculous cases of congenital dislocation of the hip, osteo-arthritic hip, spina bifida, poliomyelitis, cerebral palsy, Marie-Strümpell arthritis of both hips, and deformities resulting from poliomyelitis.

Streptomycin is used extensively (about 15 kilograms in 1950), with good results in both those treated conservatively and those treated surgically. In contrast to the experience at Costa Bella, the children tolerate paraminosolicylic acid very well, while the adults do not.

Sixty per cent. of the cases are of Pott's disease, and there are four or five patients with paraplegia; treatment has been conservative. There were also three cases of paraplegia among the children.

A physical-therapy school has been established for the training of physical therapists and physical-therapy aides.

Slovenia

Slovenia, with a population of 1,400,000, is one of the most progressive of the republics and has a high standard of living. This forward-looking attitude is reflected also in the public-health facilities and the urge to keep pace with the best standards professionally, especially in the field of rehabilitation. The capital of this republic is Ljubljana; its institutions and the attitudes of its leading surgeons and public officials bear witness to this progressive spirit.

Prof. Brecelj, the chief orthopaedic surgeon in Slovenia, also expresses this progressive attitude in the many innovations he has introduced and by his deep interest in rehabilitation. He was instrumental in developing the physical-therapy school at Rovin and that in Ljubljana. He visited the United States in 1947 and returned with many new ideas which he is anxious to develop and expand.

General Hospital

The general hospital in Ljubljana is equipped with 1,800 beds. Prof. Lavric is head of the surgical service with its 312 surgical beds. This department includes general surgery, septic surgery, and traumatology. Prof. Lavric has many of his assistants training in different specialties. One is training in neurosurgery in Paris and two others are training in plastic surgery and thoracic surgery in London. Almost 6,000 surgical operations are performed annually by Prof. Lavric and his twenty-one assistants. The need for development of a special traumatological service arose from the large number of cases with accidental injuries. Within the past three years 25,000 patients with accidental injuries have been treated in the hospital and out-patient department.

Orthopaedic Service

Located in a separate and more modern building is the orthopaedic clinic; its ninety-eight beds are hardly enough to meet the needs of its large waiting list. This service includes adults and children, although most of the children go to the department of general surgery. Here as in Sarajevo there is a high incidence of osteomyelitis. Prof. Brecelj, who is in charge of the orthopaedic service, also has supervision over, and responsibility for, the Home for Crippled Children in Kanenik with eighty beds, that in Vranko with fifty beds, and the recently opened sanatorium for osteo-articular tuberculosis at Gorica with 150 beds.

Of the cases seen here there are many accidental injuries, tuberculosis, and congenital dislocation of the hip. About twenty-five cases of poliomyelitis are admitted each year. Prof. Brecelj has been doing vitallium-cup arthoplasties with fair success. He has recently undertaken the Judet acrylic arthroplasty of the hip and presented a young woman six months after the operation with, however, only fair results. Unlike Judet, he immobilizes the leg in a plaster spica for three weeks.

Prof. Brecelj has been performing many fusions of the spine with bone grafts. He divides these operations into those employing the Albee method, in which the spinous processes are joined with the graft without sinking it down to the laminae, and the Henle procedure, in which the graft is placed in the laminae and lateral to the spinous processes.

The high incidence of congenital dislocation of the hip in Ljubljana and elsewhere in Yugoslavia makes the early recognition of this disorder almost a mandatory public-health measure. Prof. Brecelj trains the midwives and students to recognize these cases early.

In addition to the in-patients, the orthopaedic department handles from sixty to 100 out-patients a day. A small physical-therapy department serves the needs of the orthopaedic department, but it is hardly adequate to meet the needs of the traumatological service. Nevertheless, despite inadequate space and personnel, a school for physical-therapy technicians is in operation, with a balanced curriculum based on English and Canadian standards. A special feature of the course is the fact that the lectures are given in English. In this manner, most of the available literature in the field is utilized, while the students and instructors learn and improve their English at the same time.

Home for Crippled Children at Kamenik

The home at Kamenik is located about 50 kilometers from Ljubljana. It houses seventy-six children, providing complete programs of education, physical rehabilitation, and prevocational training. Of the fifty boys and twenty-six girls, the majority are cases of amputations and mutilation from land mines. Among these at the time of our visit was a ten-year-old boy with bilateral amputation and one missing eye, who wrote with his toes; and a ten-year-old boy with a left below-the-elbow amputation who was the only arm amputee wearing a prosthesis. This was a crude papier-mâché device which was used not so much for cosmetic or dress effect but as a paper weight to steady the copy book in which he was writing. Without the prosthesis, the copy book could be steadied with the stump, but only if he hunched his shoulders forward, thus creating a marked droop and postural defect. The prosthesis, for all its crudity, permitted him to sit and write with better posture, less strain, and more comfort, and thus lessened the tendency to ultimate deformity.

This large incidence of child amputees is a distinct legacy from the War of Liberation. An organized program to provide prostheses for these children has not been undertaken because of the problems of servicing necessitated by growth and changes. There were many other amputees in this institution, as well as cases of poliomyelitis, muscular dystrophy, cerebral palsy, congenital luxation of the hip, and tuberculosis of the hip.

Orthopaedic Workshop

This shop employs seventy-seven workers, most of whom have had more than four years of training; the "*Meister*" has had thirty years of experience in his craft. In 1950, 400 artificial limbs were turned out, 3,600 foot plates, and 10,000 units such as knee joints, ankle joints, and hip joints for the other shops in the country. The general character of the work is similar to that in Belgrade. An excessive amount of leather is used here as elsewhere, and this could very well be corrected.

St. Peter's Hospital in Gorica

A three-hour automobile ride through the Vipova Valley brings the visitor out of the snow and fog of Ljubljana and into the sunshine of Gorica and the Italian-Yugoslav frontier. The hospital for osteo-articular tuberculosis at St. Peter's has only recently been opened. It is a beautiful structure, built lavishly by the Italians as a home for children of Fascist aviators. Its architecture and its spacious halls and high ceilings make it one of the finest structures of its kind. There is access to terraces for out-door treatment, and its well-equipped operating rooms make it especially suitable for a sanatorium for osteo-articular tuberculosis.

Prof. Brecelj, who supervises the institution, has had a long experience in bone and joint tuberculosis. He has already handled 3,500 cases, with good documentation, and was urged to publish his results. Most of these cases were treated by the conservative method of prolonged rest and immobilization. Early surgery has been tried but has not been very successful. In several cases, Brittain arthrodesis of the hips and Albee and Henle fusions of the spine have not been successful. There have been recurrences of the lesion and, in one case, dissemination and death. However, in his hands, costotransversectomy has been very successful in Pott's disease and paraplegia. His progressive attitude toward rehabilitation is illustrated by the case of one butcher with Pott's disease, who obviously could not return to his occupation. Two beds away was an engineer with hip disease; the engineer has undertaken to train the butcher in drafting.

Immediate control of the cases at Gorica has been turned over to Dr. Franz Derganz, Prof. Brecelj's associate. He had been trained in Paris during the German occupation.

Among the patients seen were many adults who were not responding well to streptomycin and long conservative treatment. There were many cases with multiple lesions, which posed real problems.

Croatia

Zagreb, capital of Croatia, has been little damaged by the War. Of the cities visited by the writer, it is the most European; it is a cultural center, with the oldest university and the oldest medical school. The chief orthopaedic surgeon of Zagreb is Prof. Grospic.

Crippled Children's Home

Although poliomyelitis is not endemic in this area, a sufficiently large number of patients have made it necessary to establish special facilities. Here, in rather inadequate and almost primitive conditions, thirty-six children are housed and are given surgical and domiciliary care and some educational training. The patients here are almost entirely victims of poliomyelitis; the usual operations of tenotomy, tendon transplantation, and arthrodesis are carried out by Prof. Grospic's assistant. More than 500 children are on the waiting list. Children with defects of the lower extremity are given priority to enable them to walk to school, and very little work is done on the upper extremities. There are no cases of osteo-articular tuberculosis, the latter being referred to the sanatoria in Dalmatia. Some of the children here are sent for further convalescence to *Kraljevica Ostro* on the Dalmatian Coast.

Orthopaedic Clinic

A visit was made with Prof. Grospic and his staff to the orthopaedic clinic. Though it is located in a modern building, its sixty beds are hardly adequate for immediate needs and the tremendous backlog of cases on the waiting list. The patients are housed in small rooms containing six to eight beds, except for the children who are in large wards with about fifteen to twenty beds. Among the adult patients seen were those with arthroplasty of the hip for old subluxations, Zahradníček operations for unreduced congenital dislocations of the hip, epiphysiolysis with Smith-Petersen nailing, tuberculosis of the knee with osteotomy, gunshot wounds in the left thigh and ankylosis of the left knee and hip in a woman army officer; others were recovering from subtrochanteric osteotomy for tuberculosis of the hip, an Albee bone graft for arthritis in the lumbrosacral joint, and multiple reconstruction procedures for bilateral ankylosis of the elbow. Of this entire group of adult patients, there was only one patient with deformity due to poliomyelitis for whom a supracondylar osteotomy had been performed.

Other adults were being treated for old dislocation of the shoulder, meniscus injury to the knee, pseudarthrosis of the femur following gunshot wounds, old osteomyelitis of the femur, cervical tuberculosis with retropharyngeal abscess, paraplegia following poliomyelitis, pathological dislocation of the hip, and osteoarthritis of both hips treated with vitallium-cup arthroplasty. Prof. Grospic has had extensive experience with vitallium-cup arthroplasty and with the Zahradníček operation for unreduced congenital dislocation of the hip.

Among the children seen in the wards, there were eleven who were convalescing from Zahradníček operations. The best results were obtained in the age group of seven to ten years. Other cases included a vitallium-cup arthroplasty in a ten-year-old child with congenital dislocation of the hip, a triple arthrodesis for a deformity of the foot due to poliomyelitis, and a case with congenital absence of the ulna with bowing of the forearm and absence of three fingers. A case of arthrogryposis had been given special attention here, with careful dissection and histological studies by one of the members of the staff. In the 525 operations performed by Prof. Grospic, the order of incidence of defects was as follows: (1) congenital abnormalities, including congenital dislocation of the hip and pes equinus; (2) tuberculous lesions; (3) deformities due to poliomyelitis; (4) rickets; (5) rheumatism; (6) static defects; (7) injuries.

Library

A visit to the library in the orthopaedic clinic revealed a small but satisfactory collection of modern publications in the field of orthopaedics. Expansion of the library to meet the present-day needs of the orthopaedic surgeon is certainly required. Journals especially are needed. Among the books noted were those of Florschutz. His was the first book on fractures published in the Balkans, and in it the Balkan frame is described for the first time. The use of the Balkan frame has been a standard procedure in fracture treatment and, with slight modifications, has continued to be.

General Hospital

This is an old hospital which had been improvised from a home for the chronically ill. It contains 600 beds, of which 123 are devoted to orthopaedic surgery and traumatology. The orthopaedic service receives patients with injuries to the spine and the femur, and complicated cases; the others are sent to the surgical service.

Among the patients in the orthopaedic service were many with osteo-articular tuberculosis, one with paraplegia; a girl with a Chopart amputation of the foot for whom a tendon lengthening had been done, with results that were still poor; a patient with fracture of the elbow, with myositis ossificans; one with paraplegia due to poliomyelitis; and one with spastic paralysis due to scoliosis, with contractures of both knees.

In this hospital there were three orthopaedic surgeons, one of whom was a woman graduated in 1941. Another, Dr. Deljic, had recently returned from Montenegro where he had practised for three years as an orthopaedic surgeon.

Montenegro has a population of 400,000. There are two orthopaedic hospitals, one at Budva with 300 beds and the other at Risan with 300 beds. Half of the beds at the Risan hospital are for patients with osteo-articular tuberculosis and the rest are for general orthopaedics. Dr. Deljic cared for more than 280 congenital dislocations of the hip and over 300 cases of poliomyelitis in the three years of his work at Montenegro. He advised me that most of the poliomyelitis cases are severe and require surgical procedures, and that only meager facilities are available for muscle reeducation. Only one nurse trained in massage was available for all of these patients. There were almost fifty cases of cerebral palsy. He estimates that over one thousand persons are without needed orthopaedic treatment in Montenegro.

Dr. Deljic was trained at Zagreb, and later by Prof. Ombrédanne and Prof. Sorrel in Paris. Before his three years at Montenegro he had spent twelve years at Kraljevica. Dr. Deljic showed me a plan for an orthopaedic "city" to meet the total orthopaedic needs of the entire country of Yugoslavia. Among the various buildings that would make up this orthopaedic "city" was a 2,000-bed institution for osteo-articular tuberculosis. The scheme showed excellent imagination and planning; but, until an adequate number of personnel can be trained for such a project, it will remain only a hope for the distant future.

Orthopaedic Shop

This shop was established during World War I, and in 1938 moved to its present quarters. It employs 264 persons, and per year produces over 1,500 artificial limbs, 12,000 orthopaedic shoes, 12,000 foot plates, and various other devices.

The orthopaedic, brace-making, and limb-making industry in Yugoslavia stems in large measure from the work of Jacov Hlvaka, a Czechoslovakian who came to Zagreb fifty years ago and became the first limb-maker in the Balkans. The elder Hlvaka has since died, and his place is now nationalized; his son, a physician, is now employed in the local traumatological hospital.

Traumatological Hospital

Because of the increase in accidental injuries, special traumatological institutes have been set up in the chief cities. The one in Zagreb has 120 beds, with a well organized ambulance service, emergency facilities, and provision for immediate hospitalization. The surgical treatment is excellent, with good reduction of fractures, many by the open method; but, unfortunately, there is very little systematic after-care. Only one physical therapist is employed. There were 17,482 persons treated as in-patients and out-patients during 1950. The entire treatment program was managed by four doctors.

Polyclinic

A visit to the central polyclinic, particularly the physical-therapy department, was most revealing. This large building has an extensive hydrotherapy department, including a large swimming pool, steam baths, mud baths, and a wide variety of hydrotherapeutic devices usually seen in elaborate spas rather than in medical institutes.

An extensive physical-therapy department is associated with this hydrotherapy department. The work to a large extent is carried on by aides with little or no training in the field. They were simply machine-tenders who turned the machines on and off according to the instructions of the doctors. Over 600 patients a day were treated, and sometimes as many as a thousand. Periods of treatment were short, with no relationship to an integrated program of rehabilitation.

Summary

This six weeks' survey of orthopaedic facilities and needs in Yugoslavia was deeply impressive. Against the heaviest odds and in spite of tremendous obstacles—such as shortage of personnel, supplies, and hospital beds—the doctors have carried on with great devotion to duty, professional loyalty, and technical competence. Much has been accomplished, but more remains to be done. Yugoslav physicians have been isolated from the medical advances of the past ten years made or recorded in the English language. In a personal interview with Marshall Tito, I brought this matter to his attention. He agreed that doctors should be given every opportunity to read the literature in their field, although he pointed out the difficulties in language.

Arrangements are now being made, following the writer's recommendations, by the Technical Assistance Administration of the United Nations, to promote fellowships for Yugoslavia, and for Yugoslavia to establish orthopaedic facilities and rehabilitation centers to meet the needs of its 500,000 physically handicapped persons.

GEORGE KENNETH COONSE

1897–1951

Ken, the name by which he was always known, was born in Seattle, Washington, in 1897 of Scotch parentage. His mother died shortly after his birth; he therefore had no remembrance of her. He was brought up largely by an aunt, for his father was away a great deal. His early education was received in the public schools of Seattle. He was graduated from Leland Stanford University in 1920, where his education included a premedical course. He entered Harvard Medical School in 1920 from which he was graduated in 1924. He may be styled a "self-made man", since the expenses of his education were, for the most part, met by what he earned in outside work.

He was appointed Professor of Orthopaedic Surgery at the University of Missouri and Director and Chief Surgeon of the State of Missouri Crippled Children's Service. He was a veteran of World War I and a commissioned surgeon in the Public Health Service Reserve Corps. His application for service in World War II was refused after two examinations, because of high blood pressure.

He was what might be termed a prolific writer. His contributions to medical literature date from 1929, when, in collaboration with Dr. Nathaniel Allison, he wrote an article entitled "Synovectomy in Chronic Arthritis". This was followed by about twenty-five articles, many of them being written jointly with other men; but one can recognize the originality and initiative of Ken throughout the articles. He also contributed a very valuable series of chapters to a book written by Dr. Robert Mason under the title of *Preoperative and Postoperative Treatment*.

At the time of his death he was an Associate in Orthopaedic Surgery at Harvard Medical School; Director of the Infantile Paralysis Clinic, Boston City Hospital; in charge of orthopaedic teaching at the Boston City Hospital through Harvard Medical School; Visiting Surgeon at Boston City Hospital; Orthopaedic Surgeon-in-Chief at the Newton-Wellesley Hospital; and Consulting Orthopaedic Surgeon to several out-of-town hospitals around Boston.

He was a diplomate of the American Board of Orthopaedic Surgery, a member of the American Medical Association, a Fellow of the American College of Surgeons, a Fellow of The American Academy of Orthopaedic Surgeons, and a member of The American Orthopaedic Association.

It is not a difficult task for a friend who knew him intimately to eulogize Ken Coonse. Strange to say, this man was very shy and diffident and he had comparatively few intimate friends. People were attracted to him for the charm of his personality; and members of the profession recognized his ability, both as a surgeon and as a counselor. In his skill as a surgeon, he embodied the necessary qualifications of experience and judgment.

Ben Jonson once said: "That old bald cheater, Time; beware of him". I know of no other person to whom these words can be more aptly applied than to our friend Ken. Time meant nothing to him except as the medium in which he could do the things he liked to do best. Many of his original thoughts unfortunately never came to fruition. He never allowed anything to interfere with his daily exercise, which included a three-mile run every morning with his dog, or a twelve-mile row on the river in his shell, or a game of handball at the Union Boat Club. A fact little known to anybody except his intimate friends was that he was a diving champion on the Pacific Coast. He defied the elements; he never wore an overcoat, undershirt or vest, rubbers or overshoes, and was, in the judgment of all of us who knew him so well, the picture of health and physical fitness.

He abhorred hypocrisy; he was sincerely honest in all his dealings, and his criticisms of individuals were always constructive. He never ventured an opinion unless he was asked for it. He could be termed a "seeker of truth". He was kind, modest, and gentle, ever thoughtful of the needs and desires of his friends and family. He possessed a certain quality of thoroughness, based upon a definite method and plan, and he never failed to practise the art of discretion. One of his outstanding characteristics was the charm of his humility. He accepted his failures in surgery or on controversial matters always with a smile and never with resentment.

His life was full of things well done and presented such a wide field of activities that it is difficult to enumerate them. His great love was his farm, around which his entire life developed. He never recognized physical fatigue, and the products of his farm were generously contributed to all his friends and to the needy of the community.

His sudden death has left a void which will not be filled in the hearts of his friends. His passing is a great loss to the medical profession, as his original ideas would certainly have furnished many scientific contributions to orthopaedic surgery. As a tribute to his memory, we all can say that he was a master surgeon, a wise counselor, a loyal friend, and a prince of good fellows.

HOMER D. DUDLEY

1877–1950

Homer D. Dudley died on August 8, 1950, after a short illness, at the Swedish Hospital in Seattle, Washington, at the age of seventy-two. His death brought sorrow to his many friends and colleagues, by whom he was held in high esteem, both as a man and as a surgeon.

Homer Dudley was born on September 8, 1877, in Iowa. He was graduated from Northwestern University Medical College in 1902; and he served as an intern at Provident Hospital, Chicago. He first practised in Winona County, Minnesota. In 1905, he began his practice in Seattle. During the First World War, he served as a Captain.

In 1910, he was elected a member of the King County Medical Society, and in 1920, he became president of that Society. He also served for many years as a trustee of the Washington State Medical Association and was a member of the House of Delegates of this Association, serving also as a member of the Executive Committee, and as chairman of several other committees. In 1940 he was elected President of the Washington State Medical Association.

He had been president of the Pacific Coast Surgical Society. He was a Fellow of the American College of Surgeons and a member of the American Society for Surgery of the Hand.

In 1945, he served on the joint medical-dental board which sponsored the initial legislation creating the medical and dental schools at the University of Washington.

FREDERICK CLINTON KIDNER

1879–1950

Dr. Frederick Clinton Kidner, widely known orthopaedic surgeon, died in Detroit on October 20, 1950. Born on April 13, 1879, at Ipswich, Massachusetts, he received his preliminary education in Boston and at St. Marks School. He was graduated from Harvard University, receiving his A.B. degree in 1900 and his degree of M.D. in 1904. Following his graduation from Harvard Medical School, he served as intern at the Massachusetts General Hospital in 1904–05.

Dr. Kidner early manifested an interest in orthopaedic surgery and after his internship pursued special courses in this branch of medicine in Boston. After the completion of his training, Dr. Kidner was invited to become a member of the staff of The Children's Hospital of Michigan at Detroit to develop an orthopaedic service; this he did with conspicuous success. In the years following, Dr. Kidner, in addition to his active medical career in Detroit, played a large part in the development of a state-wide Crippled Children's Service in Michigan, one of the first in this country.

In April, 1917, Dr. Kidner married Marjory Mellish of Detroit. While on their honeymoon, he was called to active service in the Army as a Captain and was immediately sent to England with the first group of orthopaedic surgeons assigned to help Sir Robert Jones in his work with British casualties. He was stationed at the Military Orthopaedic Hospital at Shepardsbush until 1918, when he was promoted to the rank of Major and made Consultant in Orthopaedic Surgery for the British Isles; this position he held until the end of the War.

Dr. Kidner contributed extensively to orthopaedic literature throughout his active life. His publications covered a wide range of subjects and added greatly to orthopaedic knowledge and techniques. Probably the outstanding characteristics of his writings were their conservatism and soundness; he was not one to be carried away by new ideas just because they were new, but was always ready to accept new proposals which had been thoroughly tested by time and experience.

Frederick Clinton Kidner was greatly honored in his time. He was a member of The American Orthopaedic Association, serving as its President in 1937–38, and a member of the Clinical Orthopaedic Society. He was a Fellow of The American Academy of Orthopaedic Surgeons and the American College of Surgeons. He was Associate Professor of Orthopaedic Surgery, Emeritus, Wayne University School of Medicine;

FREDERICK CLINTON KIDNER

Surgeon-in-chief, Emeritus, of Orthopaedics at the Children's Hospital of Michigan; Retired Chief Surgeon of the Department of Orthopaedics at Harper Hospital; Visiting Orthopaedic Surgeon, Pontiac General Hospital and Wyandotte General Hospital; Consultant in Orthopaedic Surgery at the Woman's and Receiving Hospitals, Detroit.

Above and beyond these tangible evidences of respect and appreciation was the esteem of his colleagues and those who were privileged to be his friends and the love which came to him from those, especially the crippled children of his state, who through his skill and devotion were restored to health and usefulness.

GATHORNE ROBERT GIRDLESTONE, M.A., D.M. (OXFORD), F.R.C.S.

1881–1950

G. R. Girdlestone died December 30, 1950. The facts of his life are many and varied and will have been recorded in detail elsewhere. Through his death, orthopaedic surgery has lost a man who, more than anyone else, stood for service to the crippled of all ages and races. Orthopaedic surgery has also lost one of the most fascinating and lovable characters with whom the profession has been graced.

He was deeply grounded in Oxfordshire, having been born there, in 1881, the son of an honorary Canon of Christ Church. He attended New College at Oxford whence he was graduated. Oxford also witnessed the mature developments of his career. Following his formal training at St. Thomas's Hospital, he served for five years at Oswestry in the hospital that later became the Robert Jones and Agnes Hunt Orthopaedic Hospital and, during that time, came under the guidance of Sir Robert Jones and Dame Agnes Hunt.

An accident at this time affected his lung, and it was after this injury that he dedicated his life to the care of cripples. From his father he inherited a deeply religious nature which shone through every aim and accomplishment of his life.

His lasting monument is the Wingfield-Morris Orthopaedic Hospital at Oxford with its 268 beds, together with the regional plan for the care of cripples in Oxfordshire. Having developed an orthopaedic center in Oxford for the Royal Army Medical Corps during the First World War, he afterward gained control of some huts erected for this center and established a ward of twenty-two beds for crippled children. He later obtained control of the entire group of buildings. His devotion to the cause of cripples enlisted the interest of Lord Nuffield in 1930, and through his generosity the Hospital was rebuilt and formally opened in 1933. On that occasion, when thanks were expressed to Lord Nuffield for the rebuilding of the Hospital, he replied that it was not he who had built the Hospital but G. R. Girdlestone. In May 1930 he was made Nuffield Professor of Orthopaedic Surgery, the first chair of orthopaedic surgery in Great Britain. His dedication to the cause of orthopaedic surgery led him to resign the professorship in 1942 to make way for a younger man.

Mr. Girdlestone's interests were not confined to Oxford alone. In 1919, together with Sir Robert Jones, he initiated a plan for the organization of crippled children's work on a regional basis, — a plan which seemed an idealistic dream at the time. This led to the organization of the Central Council for the Care of Cripples. All of this has come into being in Oxfordshire with its base at the center he established at the Wingfield-Morris. In 1937, he visited South Africa for Lord Nuffield to prepare plans for the development of orthopaedic surgery there.

Men from all over the British Empire and the United States came to him for specialized training. Some remained as permanent members of the staff. In 1942, he brought about the transfer of the American Hospital in Britain from Basingstoke to the newly completed Churchill Hospital at Oxford, close to the Wingfield-Morris and to his home. I was privileged to direct the unit of the American Hospital there from February through August of 1942, when Churchill became the first operating base hospital of the United States Army in England. During that period of intimate association with G.R.G., he exerted a very permanent and profound impression upon me.

As a person, he was amazing, lovable, frank, and straightforward. Deeply religious by nature, he could tolerate no subterfuge or indirection. He was essentially a crusader, motivated by enormous emotional drives to the highest of goals, most of which were successfully achieved. His conception of medicine was grounded on service to human beings; and he suffered frustration when this conception was not equally grasped by those with whom he was associated.

He was devoted to physical fitness, had participated in cricket and other sports in his university days, and always maintained his game in both golf and tennis. Many will remember the episode during his attendance at an American Orthopaedic Association meeting at Toronto when, during the accompanying golf tournament, he claimed a handicap of only 1. He would not have regarded himself as honest had he not stated his real handicap. He, of course, won the tournament. As late as the fall of 1950 he spent a vacation playing thirty-six holes of golf a day in Scotland, and reached the semifinals of the tournament at St. Andrews.

He loved to walk, and many a late afternoon I spent with him on the hills surrounding Oxford, looking down on the ancient city and conversing with him of many things. He gave one a tremendous lift, because all of his life, he fearlessly practised an idealism and thus he gave renewed courage to those who wanted to cling to idealism in this troubled world. He was keenly appreciative of the difficulties of others. He was responsible for bringing the American Hospital in Britain to Oxford, and it is safe to say that it could not have so happily maintained itself there during its stay without his constant and devoted loyalty, friendship, and guidance. He had those qualities which caused many men to love him. His passing is the end of something more glorious than the bare facts of his career can possibly disclose.

A letter written by a great and good medical friend of his arrived a few days after Girdlestone's death, from which the following quotation is taken: "For G.R.G. is not only one of the great ones of orthopaedics, but one of the great ones of our time, though his humility is such that only those who know him well appreciate his goodness and his greatness. I fear greatly for his recovery; and yet, if his time has come, the trumpets will surely sound for him on the other side."

The establishment by Lord Nuffield of a foundation of ten thousand pounds in memory of G. R. Girdlestone, to aid and assist in bringing students of orthopaedics overseas to the Wingfield-Morris Hospital, is an expression of appreciation of this great and good man.

Edward Harlan Wilson, M.D.

News Notes

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Sixty-fourth Annual Meeting of The American Orthopaedic Association will be held at the Greenbrier, White Sulphur Springs, West Virginia, on June 20, 21, 22, and 23, 1951, under the presidency of Dr. James S. Speed.

The tentative program of the Meeting, as submitted by the Program Committee, is as follows:

Wednesday, June 20

1:00 P. M. Executive Session

Afternoon Session

The Inorganic Component of Bone as Demonstrated by the Electron Microscope.
Robert M. Robinson, M.D., Rochester, New York (by invitation).

A Comparative Study of Bone-Grafting Materials.
Robert D. Ray, M.D., Seattle, Washington (by invitation).

Treatment of Non-Union in Compound Fractures with Infection.
Mather Cleveland, M.D., New York, N. Y.;
Edward M. Winant, M.D., New York, N. Y. (by invitation).

Pedicle Bone Graft in Congenital Pseudarthrosis.
A. W. Farmer, M.D., Toronto, Ontario, Canada.

End-Result Study of the Surgical Treatment of Perthes' Disease.
Paul B. Steele, M.D., Pittsburgh, Pennsylvania.

Effect of Cortisone on Healing of Experimental Fractures.
J. Albert Key, M.D., St. Louis, Missouri;
Richard T. Odell, M.D., St. Louis, Missouri (by invitation);
Lloyd Taylor, M.D., St. Louis, Missouri (by invitation).

Thursday, June 21

Morning Session

Experimental Studies in Transplantation of Whole Joints.
Charles H. Herndon, M.D., Cleveland, Ohio (by invitation).

Stenosing Tenosynovitis. A Simplified Surgical Management.
Walter C. Graham, M.D., Santa Barbara, California.

Recurrent Dislocation of the Patella.
Ian Macnab, M.D., Toronto, Ontario, Canada (by invitation).

Sarcomata of the Soft Somatic Tissues.
George T. Pack, M.D., New York, N. Y. (by invitation).

Periarticular Calcification following Poliomyelitis.
Joseph A. Freiberg, M.D., Cincinnati, Ohio.

Replacement Reconstruction of the Hip.
Harold R. Bohlman, M.D., Baltimore, Maryland (by invitation).

Friday, June 22

Morning Session

Treatment of Congenital Dislocation of the Hip by Colonna Type of Arthroplasty.
Frederic C. Bost, M.D., San Francisco, California;
Edwin R. Schoffstedt, M.D., San Francisco, California (by invitation);
Loren J. Larsen, M.D., San Francisco, California (by invitation).

Some Histophysiological Problems Peculiar to Calcified Tissues.
Arthur W. Ham, M.D., Toronto, Ontario, Canada (by invitation).

The Present Status of Surgery in Rheumatoid Arthritis with Special Reference to Experience with Cortisone.
William H. Bickel, M.D., Rochester, Minnesota;
Ralph K. Ghormley, M.D., Rochester, Minnesota.

Presidential Address.
James S. Speed, M.D., Memphis, Tennessee.

SATURDAY, JUNE 23

Morning Session

Iliopsoas Transfer for Hip-Abductor Weakness.
W. T. Mustard, M.D., Toronto, Ontario, Canada (by invitation).
The Normal Osteohistology of the Senescent Vertebra.
Edgar M. Bick, M.D., New York, N. Y.
Symposium: Streptomycin in Bone and Joint Tuberculosis.
David Bosworth, M.D., New York, N. Y.;
H. F. Coulthard, M.D., Toronto, Ontario, Canada (by invitation);
E. I. Evans, M.D., Minneapolis, Minnesota (by invitation);
Philip Moore, M.D., Mount Edgecumbe, Alaska (by invitation).
Arthroplasty of the Elbow.
Robert A. Knight, M.D., Memphis, Tennessee (by invitation).

Noon: Final Executive Session

The Annual Banquet will be held Friday evening, June 22.

AMERICAN MEDICAL ASSOCIATION
SECTION ON ORTHOPAEDIC SURGERY

ATLANTIC CITY, NEW JERSEY, JUNE 11 TO 15, 1951

OFFICERS OF SECTION

Chairman.....Walter P. Blount, M.D., Milwaukee, Wisconsin
Vice-Chairman.....Frederic C. Bost, M.D., San Francisco, California
Secretary.....Charles N. Pease, M.D., Chicago, Illinois
Executive Committee.....David M. Bosworth, M.D., New York, N. Y.
Joseph S. Barr, M.D., Boston, Massachusetts
Walter P. Blount, M.D., Milwaukee, Wisconsin

WEDNESDAY, JUNE 13

9:00 A.M.

Complications of Non-Union of Fractures with Modern Treatment (Lantern Demonstration).
Frank G. Murphy, M.D., Chicago, Illinois.
Discussion: George O. Eaton, M.D., Baltimore, Maryland;
Richard T. Hudson, M.D., Louisville, Kentucky.
Complications of Orthopaedic Surgical Procedures (Lantern Demonstration).
George J. Garceau, M.D., and Eugene Salvati, M.D., Indianapolis, Indiana.
Discussion: I. William Nachlas, M.D., Baltimore, Maryland;
Frederick R. Thompson, M.D., New York, N. Y.
Acromioclavicular Dislocation Treated by Transference of the Coraco-Acromial Ligament (Lantern Demonstration).
Julius S. Neviaser, M.D., Washington, D. C.
Discussion: Darrell O. Overpeck, M.D., Fresno, California;
Andrew Schildhaus, M.D., Brooklyn, New York.
Glenoid Shelf Operation for Recurrent Dislocation of the Shoulder (Lantern Demonstration).
Jesse T. Nicholson, M.D., Philadelphia, Pennsylvania.
Discussion: Frederic C. Bost, M.D., San Francisco, California;
J. Hamilton Allan, M.D., Charlottesville, Virginia.
Radiohumeral Synovitis (Lantern Demonstration).
Moore Moore, Jr., M.D., Memphis, Tennessee.
Discussion: Frederick M. Smith, M.D., New York, N. Y.;
Milton C. Cobey, M.D., Washington, D. C.
Non-Neurologic Lesions Simulating Protruded Intervertebral Disk (Lantern Demonstration).
Herman Young, M.D., Rochester, Minnesota.
Discussion: David M. Bosworth, M.D., New York, N. Y.;
Robert J. Joplin, M.D., Boston, Massachusetts.

THURSDAY, JUNE 14

9:00 A.M.

The Use of Preserved Tissues in Orthopaedic Surgery (Lantern Demonstration).
Captain F. P. Kreuz, Medical Corps, United States Navy;

Lieutenant G. W. Hyatt, Medical Corps, United States Navy;
Lieutenant (j.g.) T. C. Turner, Medical Corps, United States Naval Reserves;
Lieutenant C. A. L. Bassett, Medical Corps, United States Naval Reserves.
Discussion: Philip D. Wilson, M.D., New York, N. Y.;
Alan DeF. Smith, M.D., New York, N. Y.;
Lenox D. Baker, M.D., Durham, North Carolina.

Medullary Fixation of the Femur, Indications, Technique, Complications and Errors (Lantern Demonstration).
Hugh Smith, M.D., Memphis, Tennessee.
Discussion: Edwin F. Cave, M.D., Boston, Massachusetts;
Colonel August W. Spittler, Washington, D. C.

Chairman's Address: Control of Bone Length (Lantern Demonstration).
Walter P. Blount, M.D., Milwaukee, Wisconsin.

Congenital Scoliosis (Lantern Demonstration).
John G. Kuhns, M.D., and Robert S. Hormel, M.D., Boston, Massachusetts.
Discussion: Arthur Steindler, M.D., Iowa City, Iowa;
Samuel Kleinberg, M.D., New York, N. Y.

Rehabilitation of Civilian Amputees: An Evaluation of 235 Amputees and the Problems of Their Rehabilitation (Lantern Demonstration).
Jack Wickstrom, M.D., New Orleans, Louisiana.
Discussion: T. Campbell Thompson, M.D., New York, N. Y.;
Henry H. Kessler, M.D., Newark, New Jersey.

FRIDAY, JUNE 15

9:00 A.M.

Principles of Internal Fixation with Plates and Screws (Lantern Demonstration).
Leonard T. Peterson, M.D., Washington, D. C.
Discussion: Paul C. Colonna, M.D., Philadelphia, Pennsylvania;
Francis W. Glenn, M.D., Miami, Florida.

The Use of Cancellous Bone Grafts in Those Fresh Fractures Which Come to Open Reduction (Lantern Demonstration).
Maurice M. Pike, M.D., and J. Whitfield Larrabee, M.D., Hartford, Connecticut.
Discussion: H. Earl Conwell, M.D., Birmingham, Alabama;
Alexander Aitken, M.D., Boston, Massachusetts.

Medullary Fixation in the Forearm (Lantern Demonstration).
Dana M. Street, M.D., Memphis, Tennessee.
Discussion: Leslie V. Rush, M.D., Meridian, Mississippi;
Robert A. Knight, M.D., Memphis, Tennessee.

Conservative Treatment of Tibial Plateau Fractures (Lantern Demonstration).
Carl E. Badgley, M.D., and Sylvester J. O'Connor, M.D., Ann Arbor, Michigan.
Discussion: John R. Moore, M.D., Philadelphia, Pennsylvania;
John T. Jacobs, M.D., Denver, Colorado.

Fractures of the Patella (Lantern Demonstration).
Rudolph S. Reich, M.D., and Norman J. Rosenberg, M.D., Cleveland, Ohio.
Discussion: J. Neill Garber, M.D., Indianapolis, Indiana;
Luther M. Strayer, Jr., M.D., Bridgeport, Connecticut.

Osteoid Osteoma in Children (Lantern Demonstration).
William T. Green, M.D., and Jonathan Cohen, M.D., Boston, Massachusetts.
Discussion: Edward L. Compere, M.D., Chicago, Illinois;
Robert B. Portis, M.D., Beverly Hills, California.

Dr. Vicente Sanchis Olmos has been appointed *Profesor Jefe del Servicio de Traumatologia, Huesos y Articulaciones del Hospital Provincial* in Madrid. Dr. Sanchis Olmos is Editor of *Cirugia del Aparato Locomotor*, published in Madrid.

The National Society for Crippled Children and Adults Inc. will hold its annual meeting at the Palmer House in Chicago from October 3 through October 6, 1951, under the presidency of Gerard M. Ungaro.

The Hospital for Crippled Children, 89 Park Avenue, Newark, New Jersey, has announced that applications for a residency in orthopaedic surgery, from July 1951 to July 1953, are now being considered. The service is fully approved for adults' and children's orthopaedics.

Many readers of *The Journal* have known Mr. J. G. Collison of The Surgical Engineering Company, Inc. in Baltimore. Mr. Collison died on February 8, soon after returning from the meeting of The American Academy of Orthopaedic Surgeons in Chicago. Through his work in the field of surgical engineering, Mr. Collison had made valuable contributions to the technical development of bone surgery.

Justin O. Zimmer, founder and President of the Zimmer Manufacturing Company, died suddenly on March 19. He has worked closely with many orthopaedic surgeons, developing equipment needed for the new techniques in this field. These surgeons are appreciative of his contribution to their work.

La Sociedad Nacional de Cirugia of Cuba has elected as officers for 1951 to 1952 the following men:

President ..... Manuel Costales Latatú, M.D.
Vice-President ..... Antonio Rodriguez Díaz, M.D.
Secretary ..... Pedro Sánchez Toledo, M.D.
Vice-Secretary ..... Luis Rodriguez Baz, M.D.
Treasurer ..... Julio Ortiz Pérez, M.D.
Vice-Treasurer ..... Tomás Armstrong, M.D.

The Fifth Congress of the **International Society of Orthopaedic and Traumatic Surgery** will be held in Stockholm, Sweden, May 21 to 25, 1951. The Secretary of the Congress is Dr. Anders Karlén, Karolinska Institutets Ortopediska Klinic, Stockholm.

The two main subjects will be: (1) Avitaminosis and Bone Changes, with Dr. R. Zanoli of Italy and Dr. E. Rutishauser of Switzerland as the principal speakers; and (2) Low-Back Pain and Sciatica. Results of Treatment, with Dr. Joseph S. Barr, of Boston, Massachusetts, as the first speaker. In addition a large number of miscellaneous papers will be presented.

The Thirty-Fifth Annual Meeting of the **Societa' Italiana di Ortopedia e Traumatologia** was held in Turin on October 21, 22, and 23. The principal subject under discussion was reconstructive surgery of the hip.

The following officers have been elected to serve for the years 1951 and 1952:

President ..... Prof. Carlo Marino-Zuco
Vice-President ..... Prof. Sanzio Vacchelli
Counselors ..... Prof. Filippi, Prof. Pais, and Prof. Del Torto
Secretary ..... Dr. Attilio Rampoldi

During the executive session, new honorary members were appointed. Among them are: Alan De Forest Smith, M.D., New York; Custis Lee Hall, M.D., Washington; Joseph S. Barr, M.D., Boston; William T. Green, M.D., Boston; Paul C. Colonna, M.D., Philadelphia, and Harrison L. McLaughlin, M.D., New York.

The Thirty-sixth Annual Meeting of the *Societa' Italiana di Ortopedia e Traumatologia* will be held in Rome in October 1951. The principal subject to be discussed will be the means of osteosynthesis in modern traumatology. Members of The American Orthopaedic Association and The American Academy of Orthopaedic Surgeons are most cordially invited to attend this meeting.

An **International Medical and Health Exhibition** and several medical and surgical meetings will be held in Turin, Italy, May 30 through June 12, 1951. It has been planned that committees of numerous Italian medical societies will meet during this period. A large attendance of physicians and surgeons from many countries is expected. The opening session will be held on the morning of May 30 and the address will be delivered by Prof. Réné Leriche.

Among the meetings of special interest to readers of *The Journal* will be sessions devoted to orthopaedic and traumatic surgery, to be held on June 4 and 5, and the meeting of the Piedmontese-Ligurian-Lombardy society of orthopaedic, traumatic, and children's surgery, to be held on June 6 and 7.

Further information about the meeting may be obtained from Prof. Ugo Camera, Director of University Orthopaedic Clinic, Palazzo delle Esposizioni al Valentino, Torino, Italy.

The *Unfallkrankenhaus* of Vienna announces a **Conference on Traumatic Surgery** to be held May 15, 16, and 17, 1951 as part of the activities connected with its twenty-fifth anniversary. The main theme of the Conference will be "The Treatment of Fractures of the Femoral Neck and of Their Complications (Necrosis of the Head and Pseudarthrosis)." Dr. Ender of Vienna will be the main speaker; Dr. Eigenthaler, Vienna, and Dr. Russe, Graz, Austria, will be among the discussors.

Other lectures announced so far include the following:

Experiences with the Bone Bank: Dr. Jörg Böhler, Vienna, Austria.

Occupational Therapy: Dr. Walther Ehalt, Graz, Austria.
Compression Osteosynthesis: Dr. Greifensteiner, Vienna.
Results of Treatment of Fresh Monteggia Fractures: Dr. Leitner, Vienna.
Five Years' Experience in the Treatment of Athletic Injuries: Dr. Meier-Stauffer, Graz, Austria.
A New Guide Pin for Nailing of the Femoral Neck: Dr. Prinstl, Vienna.
Experiences with Bunnell's Technique of Wire Suture of the Flexor Tendons: Dr. Riess, Graz.
Experiences in the Treatment of Ununited Fractures of the Navicular by Packing with Cancellous Bone: Dr. Russe, Graz, Austria.
Subcutaneous Ruptures of the Tendo Achillis: Dr. Schönbauer, Vienna.
The Use of Sympathetic Blocks in Traumatic Surgery: Dr. Titze, Graz, Austria.
Treatment of Ununited Fractures of the Bones of the Forearm: Dr. Trojan, Vienna.

Requests for further information about the Conference should be sent to Dr. L. Böhler, Webergasse 2-6, Vienna 20, Austria.

SOCIEDADE BRASILEIRA DE ORTOPEDIA E TRAUMATOLOGIA

The Ninth Congress of the *Sociedade Brasileira de Ortopedia e Traumatologia* was held in São Paulo at the *Hospital Santa Casa*, August 22 to 26, 1950, under the presidency of Dr. Renata da Costa Bomfim. The guests of honor were Dr. H. W. Meyerding of the Mayo Clinic, Rochester, Minnesota, Dr. Julius Hass of New York, formerly professor in Vienna, Dr. José Valls of Buenos Aires, and Dr. José L. Bado of Montevideo.

Besides the scientific program, this Congress included, for the first time, scientific and technical exhibits by Brazilian, American, English, Swedish, Italian, and German companies. Numerous scientific motion pictures were shown.

On the scientific program there were two official reports. The first, "Osteotomies", by Prof. Dagmar Chaves, discussed these procedures in non-traumatic deformities. His conclusions were as follows:

1. With the development of improved equipment for osteosynthesis, metallic fixation has become more widely applicable;
2. The subtrochanteric osteotomies for the correction of alignment or for pelvic support are being used widely, besides reconstructive surgery;
3. In marked deformities several successive osteotomies should be performed.

On this same subject, R. Costa advocated a curvilinear osteotomy for supracondylar osteotomies of the femur. For osteosynthesis of supracondylar fractures of the femur, H. de Gois described the use of the Blount blade-plate.

The second official report was on "Fractures of the Shaft of the Femur", by M. Lazzareschi. In a review of 200 cases, he found that conservative methods had produced good results when well executed, although they necessitated good nursing care, considerable equipment, and prolonged hospitalization. Surgical methods had also given good results, the intramedullary fixation of Küntscher being preferred. A tendency to abandon immobilization in plaster casts was apparent.

Dr. M. Weinberger reported a series of 316 fractures of the femoral shaft and forty-three osteosyntheses from the *Hospital de Pronto Socorro do Rio de Janeiro*. He found bad results from conservative methods. He preferred osteosynthesis, using long thick plates of the Venable type, and avoiding the use of plaster casts.

Dr. Meyerding presented a new classification of giant-cell tumors, calling attention to those benign lesions which became malignant. Prof. José Valls and Prof. Fritz Schajowitcz described a new type of primitive reticulum sarcoma of bone, of low malignancy, yet easily mistaken for Ewing's tumor. In hip fractures Dr. José L. Bado reported complete cure in 85 per cent. of his cases, following the use of a bone graft. He stressed the value of his method in preventing aseptic necrosis. A classification of congenital dislocation of the hip, based on the study of the newborn, was presented by Dr. Julius Hass. H. Portella emphasized the importance of myelography and the lateral position of Young at operation in the treatment of intervertebral-disc protrusion.

Several papers on poliomyelitis were presented. J. V. Brandão introduced a new operative technique in the surgical treatment of the paralyzed valgus foot, utilizing a bilateral approach with a lateral and posterior incision. O. P. Campos presented a study of poliomyelitis as a social and hospital problem in Brazil. J. P. Marcondes de Souza and B. Bartolomei commented on the poor results following arthrodesis or tendon transplantation alone in cases of muscle imbalance of the foot. They stressed the value of combining arthrodesis with tendon transfer. For quadriceps paralysis, both medial and lateral flexors should be transplanted to avoid dislocation of the patella. L. Mabilde presented a study of seventy cases where novocain was used intravenously for regional anaesthesia, according to the method of Morrison-Bado as modified by Mabilde. D. C. Gonçalves and J. S. Lage presented their experiences with the acrylic endoprosthesis in arthroplasties of the hip. P. A. Moraes e Silva and H. Pisciotta reported on the conservative treatment, with traction, of trochanteric fractures in twenty-two cases. Godoy Moreira and F. Pires de Camargo introduced a modification in the technique of onlay bone-grafting. By apposing the cortical side of the graft to the fracture fragments the blood supply to the graft was hastened through the endosteum.

R. Souza Ramos reported favorably on open reduction in the treatment of fractures of the medial epicondyle even when the displacement was only moderate. In a series of 232 cases of fractures of the tibia, E. Batalha obtained good results, using bipolar fixation with Kirschner wires.

A case of myxosarcoma of the thigh was reported by R. Bomfim. Hemipelvectomy according to the technique of Gordon-Taylor was performed. A good functional result was obtained, with the patient using a prosthesis. P. A. Moraes e Silva reported eight supracondylar Callander amputations of the thigh. He stressed the advantages of this technique.

G. Wertheimer and his associates reported an anatomical and clinical study of 3,600 cases of craniocerebral injuries. The experience in plastic and reconstructive surgery at the orthopaedic and traumatic clinic of the *Hospital das Clinicas* was reported by L. de Abreu. He stressed the advantages of the skin bank in this work.

An experimental study on bone regeneration in rabbits was presented by J. L. Correa do Lago. Analyzing thirty-two cases of congenital dislocation of the hip, A. Bittar advised Leveuf's method of open reduction. O. Graner reviewed 133 cases of obstetrical trauma. In 60 per cent. of the cases with nerve lesions there were permanent sequelae, whereas a good prognosis could be expected in cases of pure osteo-articular injuries.

Dr. D. Sparvoli reported good results with intra-osseous instillation of penicillin in cases of osteomyelitis. D. Define, in cases of congenital pseudarthrosis of the tibia, reported better results with the use of the Boyd double onlay graft and the delayed method of grafting.

According to O. P. de Souza, streptomycin has changed the orthodox concepts of the surgical treatment of bone tuberculosis. Arthrodesis may now be performed in any phase of the disease. J. Sardinha and R. Alves also reported the value of streptomycin in producing sinus healing, thus allowing earlier arthrodesis.

R. Bomfim reported a series of cases of pseudarthrosis of the tibia, treated with the Armstrong split-bone-graft technique.

The officers for the present year are:

President: Dr. Oswaldo Pinheiro Campos;
Vice-President: Dr. Elias José Kanan;
General Secretary: Dr. Marino Lazzareschi;
Secretaries: Dr. Sylvio de Assis Rodrigues and Dr. Ricardo Luiz Ferreira da Costa;
Treasurer: Dr. Leopoldo Figueiredo, Jr.

Among the members elected were the following:

Members Honoris Causa: Prof. Benjamin Salles, Brazil
Dr. Renato Morganti, Brazil.

Honorary Members: Dr. H. W. Meyerding, Rochester, Minnesota
Dr. Julius Hass, New York, N. Y.
Dr. Carlos E. Ottolenghi, Buenos Aires
Dr. John Royal Moore, Philadelphia, Pennsylvania
Sir Reginald Watson-Jones, London
Prof. José Trueta, Oxford, England
Prof. Alberto Inclan, Cuba

Corresponding Member: Dr. Fred Albee, Jr., New York, N. Y.

The next Brazilian Congress will take place in Rio de Janeiro in 1952, under the presidency of Dr. Oswaldo Pinheiro Campos.

The principal subjects will be:

Arthrodesis of the Spine:
Prof. D. Define, Dr. O. P. Campos, Dr. L. I. Barros Lima, and Dr. E. J. Kanan;
Fractures of the Wrist:
Prof. F. E. Godoy Moreira, Dr. J. B. Faria, Dr. Bruno Maia, and Dr. Secco Eichenberg.

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Eighteenth Annual Convention of The American Academy of Orthopaedic Surgeons was held at the Palmer House, Chicago, January 27 to February 1, 1951, under the presidency of Dr. Guy A. Caldwell. The total registration was over 2,200.

The Audio-Visual Program under the chairmanship of Dr. Frank Stinchfield was well arranged and attracted large audiences.

The Instructional Courses under the chairmanship of Dr. Charles N. Pease were well attended. The Instructional Course Dinner was held on Monday evening. The "Information Please" Program was both instructive and entertaining. The Grand Ballroom was filled to capacity.

The Scientific Program was arranged by the Program Committee of which Dr. George O. Eaton was Chairman. The Scientific Program was presented on Monday afternoon, Tuesday, Wednesday, and Thursday forenoon, as follows:

MONDAY, JANUARY 29

Afternoon Session

Evaluation of Radio-Isotopes as an Adjunct to Surgical Diagnosis and Therapy.
Murray M. Copeland, M.D., Washington, D. C.

TUESDAY, JANUARY 30

Morning Session

Osteogenetic Potency of Periosteum, Bone, Bone Marrow, Cartilage, and Fibrocartilaginous Callus Transplanted in the Anterior Chamber of the Eye.
Marshall R. Urist, M.D., Los Angeles, California;
Franklin C. McLean, M.D., Chicago, Illinois (by invitation).
Discussion: Roscoe S. Mosiman, M.D., New Orleans, Louisiana (by invitation).

Current Concepts on the Mechanism of Calcification.
John Eager Howard, M.D., Baltimore, Maryland (by invitation).

An Evaluation of the Frozen and Freeze-Dried Cortical Homogenous Bone Graft in the Experimental Animal.
F. P. Kreuz, Captain, Medical Corps, U. S. N., Bethesda, Maryland;
George W. Hyatt, Lieutenant, Medical Corps, U. S. N. (by invitation);
T. C. Turner, Lieutenant (j.g.), Medical Corps, U. S. N. R. (by invitation);
A. G. Marrangoni, Lieutenant (j.g.), Medical Corps, U. S. N. R. (by invitation).
Discussion: Paul R. Lipscomb, M.D., Rochester, Minnesota;
James B. Weaver, M.D., Kansas City, Kansas.

Local Stimulation of Growth of Long Bones.
Charles N. Pease, M.D., Chicago, Illinois.
Discussion: Walter P. Blount, M.D., Milwaukee, Wisconsin;
A. R. Shands, Jr., M.D., Wilmington, Delaware.

Gross Osteopathology in Ancient Races.
William J. Tobin, M.D., Washington, D. C.;
T. D. Stewart, M.D., Washington, D. C. (by invitation);
D. J. O'Regan, M.D., Washington, D. C. (by invitation).

Afternoon Session

Operative Treatment of Flat-Foot.
Ben L. Schoolfield, M.D., Dallas, Texas.

An End-Result Study of Various Operative Procedures for Correcting Flat Feet.
C. H. Crego, Jr., M.D., St. Louis, Missouri;
Lee T. Ford, M.D., St. Louis, Missouri (by invitation).
Discussion (two papers): Emil D. W. Hauser, M.D., Chicago, Illinois;
Charles W. Peabody, M.D., Detroit, Michigan;
Isadore Zadek, M.D., New York, N. Y.;
Philip Lewin, M.D., Chicago, Illinois.

Clinical Evaluation of Achilles Tenotomy as an Aid in the Treatment of Intermittent Claudication.
David I. Schwartz, M.D., Pittsburgh, Pennsylvania.
Discussion: Leonard T. Peterson, M.D., Washington, D. C.;
G. deTakats, M.D., Chicago, Illinois (by invitation).

The Effect of Known Compression Forces on Fracture Healing.
Z. B. Friedenberg, M.D., Philadelphia, Pennsylvania (by invitation).

Arthrodesis of the Knee.
Harry D. Morris, M.D., New Orleans, Louisiana;
Roscoe S. Mosiman, M.D., New Orleans, Louisiana (by invitation).
Discussion (two papers): G. W. N. Eggers, M.D., Galveston, Texas;
Dallas B. Phemister, M.D., Chicago, Illinois;
David M. Bosworth, M.D., New York, N. Y.

WEDNESDAY, JANUARY 31

Morning Session

Restoring Flexion to the Paralytic Elbow.
Sterling Bunnell, M.D., San Francisco, California.
Discussion: C. E. Irwin, M.D., Warm Springs, Georgia;
Arthur Steindler, M.D., Iowa City, Iowa.

Anatomical and Clinical Studies on Intervertebral-Disc Degeneration.
Sten Friberg, M.D., Stockholm, Sweden (by invitation).

Presidential Address.
Guy A. Caldwell, M.D., New Orleans, Louisiana.
The Influence of Operation and Trauma on Metabolism.
Frederick A. Coller, M.D., Ann Arbor, Michigan.
Mechanics of Cervical Fracture of the Femur.
L. D. Smith, M.D., Milwaukee, Wisconsin.
Discussion: Edward J. Haboush, M.D., New York, N. Y.;
H. Earle Conwell, M.D., Birmingham, Alabama.

Afternoon Session

The Nature of Rheumatoid Arthritis and Its Management.
Walter Bauer, M.D., Boston, Massachusetts (by invitation).
Roentgenographic Development of the Hip and Its Application to the Detection of Slipped Capital Femoral Epiphyses.
Armin Klein, M.D., Boston, Massachusetts;
Robert J. Joplin, M.D., Boston, Massachusetts;
John A. Reidy, M.D., Boston, Massachusetts;
Joseph Hanelin, M.D., Boston, Massachusetts (by invitation).
Discussion: Albert Ferguson, M.D., Brookline, Massachusetts;
Robert W. Johnson, Jr., M.D., Baltimore, Maryland.
Open Reduction in Congenital Dislocation of the Hip.
M. Beckett Howorth, M.D., New York, N. Y.
Discussion: H. R. McCarroll, M.D., St. Louis, Missouri;
Wallace H. Cole, M.D., St. Paul, Minnesota.
Acute Osteomyelitis in Infants.
Donald W. Blanche, M.D., Los Angeles, California.
Treatment of Suppurative Arthritis by Antibiotics.
Alan DeF. Smith, M.D., New York, N. Y.
Discussion (two papers): F. R. Wilkinson, M.D., Toronto, Canada (by invitation);
Jesse T. Nicholson, M.D., Philadelphia, Pennsylvania;
Carl E. Badgley, M.D., Ann Arbor, Michigan;
J. Albert Key, M.D., St. Louis, Missouri.

THURSDAY, FEBRUARY 1

Morning Session

One Hundred Fifty Suction Socket Prosthesis Wearers Followed from One to Five Years.
Robert Mazet, Jr., M.D., Los Angeles, California;
Paul E. McMaster, M.D., Los Angeles, California;
Charles G. Hutter, M.D., Los Angeles, California (by invitation).
Discussion: Augustus Thorndike, M.D., Boston, Massachusetts (by invitation);
James McAteer, M.D., New York, N. Y.;
Charles O. Bechtol, M.D., Oakland, California.
Cineplastic Muscle Motors for Prostheses of Arm Amputees.
Colonel August W. Spittler, Medical Corps, U.S.A., Washington, D. C. (by invitation).
Discussion: Rufus H. Alldredge, M.D., New Orleans, Louisiana;
Henry H. Kessler, M.D., Newark, New Jersey.
Giant-Cell Tumor of Bone.
Marcus J. Stewart, M.D., Memphis, Tennessee;
T. A. Richardson, M.D., Calgary, Alberta, Canada (by invitation).
Discussion: Lent C. Johnson, M.D., Washington, D. C. (by invitation);
Charles F. Geschickter, M.D., Washington, D. C. (by invitation).
Bone Metastases of Neurogenic Tumors of the Sympathetic Nervous System in Children.
E. William Immermann, M.D., Chicago, Illinois (by invitation);
Edward L. Compere, M.D., Chicago, Illinois.
Discussion: William H. Bickel, M.D., Rochester, Minnesota;
William T. Green, M.D., Boston, Massachusetts.

The First Executive Session was held at 3:45 p.m. on Monday, January 29. The Second Executive Session was held at 11:50 on Thursday, February 1. On Monday afternoon, membership certificates were presented to the new members. Following is a list of the newly elected Fellows:

Harry O. Anderson, M.D., Wichita, Kansas
Robert D. Anderson, M.D., Tacoma, Washington
Harvey Marvin Andre, M.D., Grand Rapids, Michigan

W. O. Badgley, M.D., Lansing, Michigan
John Frye Bell, M.D., Burlington, Vermont
Richard F. Berg, M.D., Portland, Oregon
Harry Dibblee Blunden, M.D., Los Angeles, California
Harold S. Bowman, M.D., Wichita, Kansas
Frances Elizabeth Brennecke, M.D., Chicago, Illinois
John Quincy Brown, M.D., Columbus, Ohio
Kenneth Gould Burton, M.D., Providence, Rhode Island
Crawford J. Campbell, M.D., Loudonville, New York
Louis S. Campbell, M.D., Omaha, Nebraska
Walter F. Carpenter, M.D., San Diego, California
John Watson Chenault, M.D., Tuskegee Institute, Alabama
Edward J. Coughlin, Jr., M.D., Williamstown, Massachusetts
Edward P. Daly, M.D., Bronxville, New York
Richard Charles Deming, M.D., Jackson, Michigan
Connelly Moore Dobson, M.D., Pomona, California
Philip Dohn, M.D., Eureka, California
Edward T. Driscoll, M.D., Midland, Texas
Palmer O. Eicher, M.D., Indianapolis, Indiana
John Barmore Feltner, M.D., Chili, New York
W. Richard Ferguson, M.D., Baltimore, Maryland
Michael J. Fontanetta, M.D., Glendale, New York
Kermit William Fox, M.D., Austin, Texas
Milton Freiberg, M.D., Tyler, Texas
Murray E. Gibbens, M.D., Fort Logan, Colorado
Daniel S. Giddings, M.D., New York, N. Y.
Joseph H. Giesen, M.D., Waterville, Maine
James Robert Gladden, M.D., Washington, D. C.
John Richard Glover, Sr., M.D., Nashville, Tennessee
Joseph A. Gosman, M.D., Toledo, Ohio
Leo Arthur Green, M.D., Forest Hills, New York
Harold W. Grosselfinger, Suffern, New York
Curtis M. Hanson, M.D., Kalamazoo, Michigan
T. C. Harper, M.D., Reno, Nevada
Benjamin Lee Hawkins, M.D., Cincinnati, Ohio
Frederick B. Hawkins, M.D., Toledo, Ohio
Alfred Otto Heldobler, M.D., Fort Lewis, Washington
Edward Eric Hildebrand, M.D., Fresno, California
John J. Hinchey, M.D., San Antonio, Texas
Arthur Holstein, M.D., Berkeley, California
R. Grant Howard, M.D., Kalamazoo, Michigan
Robert Ellis Ingersoll, M.D., Boston, Massachusetts
Anthony S. Ippolito, M.D., Chicago, Illinois
Ellis William Jones, Jr., M.D., Pasadena, California
William Norman Jones, M.D., Boston, Massachusetts
Luke William Jordan, M.D., Philadelphia, Pennsylvania
Jacob E. Kaufman, M.D., Green Bay, Wisconsin
Charles F. Kincheloe, M.D.*, Washington, D. C.
Paul Chandler Kingsley, M.D., Battle Creek, Michigan
Prentice Kinser, Jr., M.D., Danville, Virginia
William Alexander Larmon, M.D., Chicago, Illinois
J. Whitfield Larrabee, M.D., Hartford, Connecticut
Aldo J. Leani, M.D., Springfield, Massachusetts
Eugene Pinson Legg, M.D., Dallas, Texas
Albert L. Leveton, M.D., Los Angeles, California
Stanley M. Leydig, M.D., St. Louis, Missouri
Theodore Ayres Lynn, M.D., Los Angeles, California
Donald W. McCormick, M.D., Fond du Lac, Wisconsin
Edmond J. McDonnell, M.D., Baltimore, Maryland
Robert Hugh Mabry, M.D., Springfield, Ohio
John Duncan Macpherson, M.D., San Diego, California

* Deceased.

K. Randolph Manning, M.D., Indianapolis, Indiana
James Patton Miller, M.D., Baltimore, Maryland
William R. Molony, Jr., M.D., Los Angeles, California
M. H. Morris, M.D., San Antonio, Texas
Joseph S. Mulle, M.D., Jamaica, New York
John F. Nabos, M.D., New Orleans, Louisiana
S. Harold Nickerson, M.D., White Plains, New York
William H. Norman, M.D., Indianapolis, Indiana
Sylvester J. O'Connor, M.D., Ann Arbor, Michigan
George F. Pennal, M.D., Toronto, Ontario, Canada
James E. Pollard, M.D., Pueblo, Colorado
Samuel Bradley Prevo, M.D., Nashville, Tennessee
Ellis D. Rand, M.D., Colorado Springs, Colorado
Joseph H. Reno, M.D., Bethlehem, Pennsylvania
Joseph A. Ridgeway, M.D., Columbus, Ohio
Melville Rosenbusch, M.D., Flushing, New York
Roy Rounds, Lieutenant Colonel, Medical Corps, El Paso, Texas
M. Laurens Rowe, M.D., Rochester, New York
Gustav Rubin, M.D., Brooklyn, New York
Charles Bruce Sadler, M.D., Amarillo, Texas
Alfred G. Scheffel, M.D., Beverly Hills, California
Edmund H. Schweitzer, M.D., Cincinnati, Ohio
Arthur F. Seifer, M.D., Philadelphia, Pennsylvania
Aaron Frederick Serbin, M.D., Hartford, Connecticut
Frank L. Shipp, M.D., Boston, Massachusetts
Eugene Henry Silverstone, M.D., Coral Gables, Florida
William J. Stark, Plainview, Texas
Sidney L. Stovall, M.D., Denver, Colorado
Paul Strassburger, M.D., Belleville, New Jersey
Sam Gaines Stubbins, M.D., Cleveland, Ohio
Jack S. Sugar, M.D., Washington, D. C.
John Joseph Talin, M.D., Troy, New York
Samuel Ralph Terhune, M.D., Birmingham, Alabama
John Samuel Thiemeyer, Jr., M.D., St. Albans, Long Island, New York
George L. Thomas, M.D., Janesville, Wisconsin
Walter A. L. Thompson, M.D., New York, N. Y.
Vincent J. Turco, M.D., Hartford, Connecticut
James Howard Varney, M.D., Bakersfield, California
Leonard Weinstein, M.D., Chicago, Illinois
Leon John Willien, M.D., Knoxville, Tennessee
William J. Wilson, M.D., Wilmington, North Carolina
Benjamin R. Wiltberger, M.D., Columbus, Ohio
Philip M. Winslow, M.D., Rochester, New York
Victor Wolkin, M.D., Rochester, New York
Jesse C. Woodward, Jr., M.D., Vancouver, Washington
Kazuo Yanagisawa, M.D., New York, N. Y.

Dr. Sten Friberg of Stockholm, Sweden, was presented with a certificate of Corresponding Membership.

At the Second Executive Session the following officers and committeemen were elected:

President: Joseph S. Barr, M.D., Boston, Massachusetts
President-Elect: Francis J. McKeever, M.D., Los Angeles, California
Vice-President: John Royal Moore, M.D., Philadelphia, Pennsylvania
Secretary: Harold B. Boyd, M.D., Memphis, Tennessee
Treasurer: H. R. McCarroll, M.D., St. Louis, Missouri
Librarian-Historian: Claude N. Lambert, M.D., Chicago, Illinois
Member of Membership Committee: Edward M. Winant, M.D., New York, N. Y.
Member of Program Committee: Albert C. Schmidt, M.D., Milwaukee, Wisconsin
Member of Committee on Scientific Investigation: Paul R. Lipscomb, M.D., Rochester, Minnesota
Member of Committee on Public Relations: Custis Lee Hall, M.D., Washington, D. C.
Nominees to American Board of Orthopaedic Surgery:
Edgar M. Bick, M.D., New York, N. Y.
Charles J. Frankel, M.D., Charlottesville, Virginia

Junior Members of Executive Committee:
Charles O. Bechtol, M.D., Oakland, California
Carroll Bernard Larson, M.D., Iowa City, Iowa

The Presidential Medallion was presented to President Guy A. Caldwell by the past President, Dr. Mather Cleveland. The gavel was presented to the new President, Dr. Joseph S. Barr, by the retiring President, Dr. Guy A. Caldwell.

The Annual Dinner was held on Wednesday evening at which time the Kappa Delta Award was made to Dr. Vernon P. Thompson and Dr. Herman D. Epstein for their work on "Traumatic Dislocation of the Hip. A Survey of 204 Cases Covering a Period of Twenty-one Years". Other awards were made as follows:

Scientific Exhibits

Class I: For Originality:

1. Jack Wickstrom, M.D., and Roscoe Mosiman, M.D., New Orleans, Louisiana:
   Observation of Bone Implants in the Anterior Chamber of the Guinea Pig Eye.
2. James A. Dickson, M.D., Cleveland, Ohio, and Harry W. O'Dell, M.D., Akron, Ohio:
   Recurrent Dislocation of the Shoulder. A Phylogenetic Approach to the Problem.
3. Donald J. Magilligan, M.D.; Herbert C. Fett, Jr., M.D.; and James C. Barnett, M.D., Brooklyn, New York:
   A Presentation of Six Orthopaedic Diagnostic Problems.

Class II: For Scientific Value:

1. William J. Tobin, M.D.; D. J. O'Regan, M.D.; and T. D. Stewart, M.D., Washington, D. C.:
   Gross Osteopathology in Ancient Races.
2. Maurice B. Roche, M.D., and George G. Rowe, M.D., St. Louis, Missouri:
   The Separate Neural Arch. A Study of the Incidence from the Foetus to Maturity.
3. Dana M. Street, M.D.; F. James Funk, M.D.; and J. M. Young, M.D., Memphis, Tennessee:
   Tumor Metastases to the Lumbar Spine. Frequent Failure of Roentgenography to Reveal Lesions.

Class III: For Clinical Value:

1. Fremont A. Chandler, M.D.; Carl A. Johnson, M.D.; and Hugh Dickinson, M.D., Chicago, Illinois:
   The Recording Oscillometer in Orthopaedic Surgery.
2. Charles H. Herndon, M.D., and Clarence H. Heyman, M.D., Cleveland, Ohio:
   Legg-Perthes Disease: Results of Treatment by Traction and Ischial Weight-Bearing Brace.
3. Frederick S. Webster, M.D., and J. E. M. Thomson, M.D., Lincoln, Nebraska, and W. M. Roberts, M.D., Gastonia, North Carolina:
   Tarsal Anomalies and Peroneal Spastic Flat-Foot.

Gadget Exhibit

1. Everett I. Bugg, M.D., Durham, North Carolina, and Richard Hall, M.D., Fayetteville, North Carolina:
   Screw for Attaching Soft Tissue to Bone.
2. Allen S. Lloyd, M.D., Washington, D. C.:
   Adaptor for Smith-Petersen Nail.

The Nineteenth Annual Convention will be held at the Palmer House, Chicago, January 26 to 31, 1952, under the presidency of Dr. Joseph S. Barr.

SOCIEDAD LATINO-AMERICANA DE ORTOPEDIA Y TRAUMATOLOGÍA

The First Congress of the **Sociedad Latino-Americana de Ortopedia y Traumatología** met at Montevideo, Uruguay, and Buenos Aires and Mar del Plata, Argentina, December 9 to 17, 1950.

The Congress was organized by two committees, one in Argentina under the chairmanship of Prof. José Valls, and the other in Uruguay, with Dr. José L. Bado as chairman.

The Congress was attended by approximately three hundred of the most prominent orthopaedic surgeons from all the republics of South and Central America. It was a success in every sense, and the meetings, clinical courses, and exhibitions were found to be of great value.

The first session was held at Hotel Miramar, Montevideo, December 9, 1950, under the presidency of Dr. Alberto Inclán, Havana, Cuba. Degenerative Arthritis of the Hip Joint was discussed.

Dr. Domingo Vasquez Rolfi, Uruguay, was the first speaker. He believes that arthrodesis should be employed only when the patient cannot undergo a more difficult operation. Dr. José Valls demonstrated a model of a metallic cup for arthroplasty, his own device, which he has already used with success. He agreed, however, that, until the efficiency of arthroplasty has been proved by further experience, arthrodesis is the operation of choice for unilateral cases. Dr. Lu's A. Weber, Argentina, presented another study with the same conclusions. Dr. José A. Sgrosso, Argentina, related his experience with the Valls cup.

Dr. Leoncio Fernandez and Dr. Américo Nunziata, Argentina, reported their experience in seventy-eight denervation operations, with good results in 50 per cent. of cases. They believe this procedure is the operation of choice when antalgic methods are indicated. Dr. Oscar Scaglietti, Florence, Italy, also spoke on denervation operations, about which he was skeptical; he believes that the new types of arthroplastic operations like those of Dr. Valls should be tried.

The afternoon session was begun with a symposium on Congenital Club-Foot; the moderator was Dr. Oscar R. Marottoli, Argentina. Dr. Pedro Sánchez Toledo, Cuba, stated that early conservative treatment is the method of choice. The Denis Browne splint and Kite's method were discussed; it was agreed that surgical treatment should be reserved for severe deformity or used as a complementary measure. Dr. Guillermo Velazco Polo, Mexico, described Farill's method, which is applied during the first year of life, Kite's technique being used after that age. Farill's method of subcutaneous tenotomy of the tendo achillis was also demonstrated.

Dr. Carlos Urrutia, Chile, said that surgical procedures are indicated only in case of failure of closed manipulation. He described the procedure known as Codivilla's, Gamboa's, or Brockman's operation, and finally demonstrated his technique for transplantation of the tibialis anterior.

Dr. Marcelo Gamboa, Argentina, emphasized the importance of what may be designated as a subluxation of the talus. He described his own procedure, to be applied in certain cases.

The afternoon session closed with a symposium on Tuberculosis of the Hip Joint. The moderator was Dr. Oswaldo Pinheiro Campos, Brazil.

Dr. Guillermo Allende, Argentina, held that at present conservative treatment does not lead to sound healing, but that progress in antibiotics might make healing possible in the near future. He believes that ischiofemoral arthrodesis is the operation of choice for children.

Dr. Jorge Figarella, Venezuela, stated that for arthrodesis in patients under ten years of age he prefers Chandler's extra-articular and intra-articular technique.

Dr. Dagmar A. Cháves, Brazil, pointed out the importance of biopsy as in Ottolenghi's procedure. He has used the Brittain operation for children. In patients over thirteen or fourteen years of age he advises Ricard's technique. He believes that intrafocal procedures will be the operation of choice in the future.

Dr. Augusto Bonilla B., Ecuador, reported good results in his experience with ischiofemoral arthrodesis.

On December 11 the afternoon session began with a symposium on the Bone Bank. Dr. Carlos Urruti was the moderator. Dr. José A. Sgrosso was in charge of organization. Dr. Alberto Inclán analyzed indications and reported end results in 162 cases.

Dr. Herbert Cagnoli, Uruguay, believes that infection is the main factor in failures; he stressed the fact that the graft should be warm before use.

Dr. Alejandro Velazco Zimbron, Mexico, discussed his experimental work on animals, and his experience with 305 cases with follow-up examination out of a series of 450 operations in which bone bank grafts had been used.

The session continued with a symposium on Sciatica. The moderator was Dr. Fortunato Quesada, Peru. Dr. Roberto Olmedo, Paraguay, and Dr. Orlando Pinto de Souza, Brazil, spoke in favor of conservative treatment, stressing the importance of postural re-education and of immobilization.

Dr. Alberto Croquevielle, Chile, and Dr. Rodolfo L. Ferré, Argentina, outlined the indications for surgical treatment, to be followed by fusion operation in certain cases. Dr. Oscar Scaglietti reported his own experience in over three hundred operations. He advises a long observation period and routine lumbar puncture.

On December 13 a session was held in Buenos Aires, with the *Asociacion Médica Argentina* as host. Fractures at the Elbow Joint were discussed. Dr. Juan Farill, Mexico, discussed supracondylar fractures in children. He has been impressed by results recently obtained after open reduction and fixation. However, he feels that, while closed reduction does not lead to good results immediately, end results with both methods are usually satisfactory.

The next speaker, Dr. Teodoro Gebauer, Chile, advocated surgical treatment, if necessary for a good reduction. He pointed out the advantages of the approach described by Dr. Ros Codorniu of Madrid, and of fixation by means of screws or staples.

Dr. Jorge de Romaña, Peru, stated that closed manipulation should always be tried first and argued against internal fixation. Dr. Domingos Define, Brazil, also believes that internal fixation should be avoided. He reported on three cases of diacondylar-trochlear fractures treated operatively. Dr. Sara Satanowsky,

Argentina, advises excision of any fragment which might prevent anatomical reduction. There was general agreement on the advantages of Zeno's method of skeletal traction.

Dr. Thompson, United States, demonstrated several types of prostheses to replace the lower end of the excised humerus.

The morning session on December 15 was again held at Buenos Aires, with the *Asociacion Médica Argentina* as host, Dr. Inclán presiding. A symposium on Giant-Cell Tumors was presented. Moderator was Dr. Arturo Feria y Mora, Cuba.

Dr. Fritz Schajowicz and Dr. Silvano Mondolfo, Argentina, spoke on differentiating between true giant-cell tumors and other types of tumors. Histological studies, with special techniques, including tissue culture, prove that both giant-cell and fundamental-cell tumors have a mesenchymal origin (reticulo-histiocytic). They reported on fifty-seven cases treated by them and pointed out that, in spite of the so-called benignity of this type, there is always a certain amount of local activity, or a tendency for the tumor to grow and recur. Sarcomatous degeneration was always found after roentgenotherapy, which was administered alone or in conjunction with surgical treatment. They believe that excision should be complete. Amputation is reserved for very large growths or for sarcomatous degeneration.

Dr. Achilles de Araujo, Brazil, said that, according to his view, giant-cell tumors are to be considered as the active type of localized osteodystrophy. He presented a table showing the course followed by thirty-two cases, and a film illustrating surgical treatment. Dr. Alberto Inclán answered a question on bone-grafting, affirming that he has successfully used refrigerated bone, either cancellous or cortical, to fill large excisions.

The session closed with a lecture on peripheral-nerve injuries by Prof. Oscar Scaglietti.

The last meeting was held at the Auditorium in Mar del Plata. Short communications were presented and a symposium on Fractures of the Neck of the Femur was held. Dr. Carlos E. Ottolenghi, Argentina, was the moderator. Dr. Robert Paterson Toledo, Argentina, presented a review of the historical background of all surgical techniques employed for this fracture.

Dr. Luís J. Petracchi, Argentina, spoke on nailing, stating that the technical problem is already solved, but that avascular necrosis has not yet been eliminated. His statistical data were impressive. Two hundred cases were followed for two years or more. Seventeen cases of pseudarthrosis and sixty-four cases of necrosis occurred in this series. Dr. Edmundo de Souza Batalha spoke on screw fixation. He pointed out that better results have been observed if a hip spica is applied after operation and continued until consolidation. However, the best results, he felt, were in the group of fractures treated by screw fixation and an intertrochanteric osteotomy.

Dr. José Luis Bado, Uruguay, advises bone-grafting and a hip spica to prevent avascular necrosis. Combined grafting and nailing is reserved for those patients who are not able to endure a hip spica. No avascular necrosis has been observed in those cases treated by the former method.

Dr. Luís J. Iglesias de la Torre, Cuba, believes that osteotomy is not advisable for fresh fractures unless the Pauwels and Linton angles exceed 75 degrees. Osteotomy is an excellent treatment for pseudarthrosis, provided that necrosis or arthrosis has not previously developed.

Over forty short communications were presented.

Several clinical courses were given:

Compound Fractures	Dr. Carlos E. Ottolenghi
Tumors of Bone	Dr. Fritz Schajowicz and Dr. Jorge E. Valls
Bone Dystrophies	Dr. Domingo Muscolo, Argentina, and Jorge B. Sardinha, Brazil
Pneumo-Arthrography of the Knee Joint	Dr. Hector Dal Lago, Argentina
Intramedullary Nailing	Dr. Isidro Castillo Odena, Argentina
Surgery of the Hand	Dr. Pedro Pedemonte, Uruguay, and Dr. Felipe Oleaga Alarcón, Argentina
Congenital Dislocation of the Hip	Dr. José E. Rivarola, Argentina
External Skeletal Fixation	Dr. Alfonso Montagne, Peru, and Dr. José Manuel del Sel, Argentina

The program of medical films was successfully directed by Dr. Oswaldo Pinheiro Campos.

The Second Congress will be held as a joint meeting with the Brazilian Orthopaedic Congress at Rio de Janeiro, Brazil, in June 1952.

The Officers elected are:

Honorary Presidents:	Dr. José Valls, Dr. Achilles de Araujo, and Dr. Domingos Define
President-Elect:	Dr. Oswaldo Pinheiro Campos

AMERICAN SOCIETY FOR SURGERY OF THE HAND

BY S. BENJAMIN FOWLER, M.D., NASHVILLE, TENNESSEE AND JOSEPH H. BOYES, M.D., LOS ANGELES, CALIFORNIA

The Sixth Annual Meeting of the American Society for Surgery of the Hand was held at The Palmer House in Chicago on Friday, January 26, 1951.

Dr. Donald R. Pratt, of San Francisco, California, presented a method of internal splinting for injuries of the distal portion of the extensor apparatus of the fingers. By inserting a Kirschner wire through the terminal phalanx, across the dorsum of the distal interphalangeal joint and through the middle phalanx, then anterior to the middle joint of the finger and into the proximal phalanx, the finger is held with the middle joint in flexion and the distal joint in hyperextension. The wire is left in place until tendon union is complete. The method has been used not only for rupture of the insertion of the extensor tendon, but also for fixation following operative repair and is said to be free of complications.

Dr. H. Minor Nichols, of Portland, Oregon, discussed the repair of extensor-tendon injuries by means of tendon grafts. He reported on the repair of the insertion of the tendon into the distal phalanx following rupture in the so-called "baseball finger", and also repair of the middle slip of the extensor tendon over the dorsum of the middle joint.

Dr. Kenneth Jacques, of Los Angeles, California, discussed the basic principles of cerebral palsy as it affects the upper extremity. After classifying cerebral palsy into five major groups, he defined these and illustrated the points of differential diagnosis, noting that the first three types (spastic paralysis, athetosis, and rigidity) comprise about 90 per cent. of all the cases. Surgery is utilized in the treatment of cerebral palsy only after careful consideration and in most cases a long period of physical therapy and occupational supervision. He noted particularly the danger of surgery in athetosis. Splints and braces are often effective as preliminary steps to surgical procedures, and he stressed the importance of prolonged training after surgery in order to reap the maximum benefits.

Dr. William Cooper, of New York City, discussed the surgical treatment of the upper extremity in cerebral palsy, stating that the application of surgery in these cases is very limited, and primary consideration should be given to conservative methods such as re-education and splinting. It was noted that in some cases, when the thumb is brought out of the palm, the hand is dramatically unlocked, and active extension of the fingers made possible. This unlocking of the thumb is best obtained by ulna deviation of the wrist: if by splinting it can be demonstrated that ulna deviation will bring the thumb out of the palm and thus increase the function of the fingers, then arthrodesis of the wrist in slight dorsiflexion and full ulna deviation is recommended. In some cases, resection of the distal end of the ulna with or without tenotomy of the pronator teres restores a very satisfactory degree of voluntary supination. Other surgical procedures on the upper extremity were not recommended, and Dr. Cooper urged extreme conservatism in undertaking surgery on the upper extremity in patients with cerebral palsy.

Dr. Arthur Steindler, of Iowa City, presented "Arthritic Deformities of the Hand: Their Prevention and Treatment". With his usual detailed and careful study of the problem, Dr. Steindler outlined methods of control and prevention of deformity, and treatment of this most difficult problem. A careful study of his paper when it is published will be of value not only to surgeons, but also to those in allied medical fields.

Dr. William Frackelton, of Milwaukee, Wisconsin, discussed arthrodesis of the proximal joints of the fingers—the second of a three-part paper on arthrodeses of the joints of the hand. He demonstrated the optimum position for fusion of the proximal joints and the method of fusion to maintain length and normal contour of the knuckle area.

Dr. James Golseth, of Pasadena, California, discussed the development and use of the electromyograph. While proper equipment is essential, he emphasized that correct interpretation of the electromyogram must rest with a person well-trained in its use, that the machine itself cannot make the diagnosis. To insure accuracy, needle electrodes must be inserted into the depth of the muscle in several areas. He stressed the value of the electromyograph in poliomyelitis, and he felt that early surgical treatment, such as tendon transplantation, could now be carried out, because even after three weeks an accurate diagnosis of a paralyzed muscle can often be made. He outlined its value in the diagnosis and prognosis of peripheral-nerve injuries, and in the determination of regeneration in a nerve following its injury or repair.

A paper on reconstructive surgery of the upper extremities in poliomyelitis was presented by Dr. Don Eyler and discussed by Dr. E. C. Irwin, both of Warm Springs, Georgia. They presented the problems of evaluating the function of the forearm and hand disabled by poliomyelitis. The value of earlier and repeated examinations was emphasized, as was also the recommendation for earlier surgical intervention before complex substitution patterns become established. The importance of considering every phase of the patient's existence and his type of ambulation was dramatically illustrated.

Dr. Jerome Webster, of New York City, discussed the correction of some common congenital deformities of the hand. His paper was illustrated with many slides showing the various types of deformities (particularly syndactylism) and the methods of repair.

Dr. Gordon Grant of Victoria, British Columbia, discussed methods of treating neuromata of the hand.

He believes that primarily the development of neuromata is due to scarring and is secondary to crushing and infection. The treatment advised was a thorough revision of the stump with removal of the scar tissue. Nerves severed cleanly under tension and allowed to retract into normal tissues gave best results. In the aftercare, percussion of the painful areas was found to be of value, and in some cases division and suture of the nerve proximal to the amputation stump was found to be of benefit. Special treatments, such as ligation or alcohol injection, were not recommended. Sympathectomy was apparently not considered of much value unless vascular changes are predominant. Multiple revisions of the amputation stump are definitely contra-indicated and, if pain persists after one good, thorough revision, he believes that spinothalamic tractotomy should be considered.

A dinner and business meeting followed at The University Club. Officers for the coming year are:
President: Michael Mason, M.D., Chicago, Illinois
President-Elect: William Frackelton, M.D., Milwaukee, Wisconsin
Vice-President: Darrel Shaw, M.D., Cleveland, Ohio
Secretary-Treasurer: Joseph H. Boyes, M.D., Los Angeles, California
Historian: S. Benjamin Fowler, M.D., Nashville, Tennessee
Councilor: Walter Graham, M.D., Santa Barbara, California.

The following new members were elected:
Carrouth John Wagner, M.D., San Francisco, California
Joseph L. Posch, M.D., Detroit, Michigan
Gordon H. Grant, M.D., Victoria, British Columbia, Canada.

Dr. Julian Bruner, of Des Moines, Iowa, reported on a recent visit to various plastic-surgery and reconstructive-surgery centers in England. The meeting ended on a classical note: Dr. Leo Mayer, of New York City, played several selections on an original Stradivarius,—illustrating the use of the human hand in what is probably its most skillful development.

THE AMERICAN BOARD OF ORTHOPAEDIC SURGERY

Part I Examinations of the American Board of Orthopaedic Surgery will be given on the following dates:

Indianapolis, Indiana	April 27 and 28, 1951
Atlanta, Georgia	April 27 and 28, 1951
Washington, D. C.	May 4 and 5, 1951
San Francisco, California	May 11 and 12, 1951

The deadline for the receipt of applications for the 1952 Part II examinations of The American Board of Orthopædic Surgery is August 15, 1951.

BOOKS RECEIVED

Diabetes Guide Book for the Physician. American Diabetes Association, Inc., 1950.
Foot Mechanics for Chiropodists and Students. Leslie R. Smart, London, Baillière, Tindall and Cox, 1950.
The Physician Examines the Bible. C. Raimer Smith, New York, Philosophical Library, 1950.
Temas Ortopédicos, Fascículo I. Dr. Orlando Pinto de Souza, São Paulo, Brazil, 1950.

Book Reviews

COLOR ATLAS OF PATHOLOGY. The United States Naval Medical School of the National Naval Medical Center. Philadelphia, J. B. Lippincott Co., 1950. $20.00.

A volume of unusual value is the *Color Atlas of Pathology* prepared under the auspices of the U. S. Naval Medical School of the National Naval Medical Center at Bethesda, Maryland. The project was started in 1944 by Commander Charles F. Geschickter, Medical Corps, U. S. Naval Reserve, then Chief of Pathology at the Naval Medical School, and Captain Paul Wilson, Medical Corps, U. S. Navy, Medical Officer in Command of the Naval Medical School. Many officers of the Medical Corps, U. S. Navy, have made important contributions to the work which has had the enthusiastic support of the Surgeon General, Vice Admiral Ross T. McIntire; and Rear Admiral Clifford A. Swanson. Indeed the team work of many workers was necessary to produce this beautiful volume.

The many colored illustrations are the sterling feature of this work,—pathological specimens, photomicrographs, and photographs stand out like slides upon a screen. With each group is a brief summary of the case illustrated, with clinical notes. The x-rays reproduced have not the same excellence as the colored illustrations, but are necessary for the complete picture of the cases described.

Those who have used the *Hematology Manual*, issued by the U. S. Naval Medical School in 1945, will find the same excellent colored illustrations in the chapter, "Diseases of the Hematopoietic System".

A valuable book for the library of every surgeon and pathologist is this Color Atlas.

LEHRBUCH DER RÖNTGENDIAGNOSTIK (Textbook of Diagnostic Radiology). 5. Auflage, 2. Lieferung. Skelett. H. R. Schinz, W. E. Baensch, E. Friedl, und E. Uehlinger. Stuttgart, Georg Thieme, 1950. (Distributed by Grune and Stratton, Inc., New York, N. Y.)

The second volume of the Fifth Edition of the Textbook of Radiology by Schinz, Baensch, Friedl, and Uehlinger is now available in this country. What was said in the review of the first volume can be repeated; this book will make an excellent addition to any medical or professional library and should be at the disposal of all those interested in the roentgenographic aspects of bone conditions.

Volume 2 is a direct continuation of the text of *Volume 1* and deals exclusively with the pathology and diseases of bone. It is divided into several major parts,—aseptic necroses of the epiphyses, apophyses, and small bones; toxic osteopathies; inflammatory diseases of the bones; medullary osteopathies; changes of bones and joints or their arrangement due to developmental and congenital abnormalities—and a brief section on primary tumors of bone which is to be continued in *Volume 3*. A great deal of new material, including x-ray reproductions, sketches, and diagrams has been added to the new edition.

The aseptic necroses are well covered by subdivisions into their various forms,—the common "spontaneous"; the rarer "occupational", which occurs most frequently in caisson workers and those employed in the use of air-pressure hammers; and the many manifestations of the "traumatic" type. All these conditions are well described and illustrated by roentgenograms, sketches, charts, and statistical tables analyzing the common and unusual distribution and location of the disease.

A brief chapter deals with the effects upon bone of poisoning with such agents as phosphorus, strontium, lead, and fluorin. In this connection, however, the reader misses any reference to the effect of radio-active substances on bone; this is certainly a problem of particular importance at the present time. It is of interest to find in this chapter a description of hypertrophic osteo-arthropathy, a condition which the authors consider an expression of endogenous toxicosis secondary to chronic disease of the lung and mediastinum.

A large part of the book concerns itself with the inflammatory diseases of bone. Osteomyelitis, eosinophilic granuloma, actinomycosis, tuberculosis, and syphilis are comprehensively discussed, and other rarer inflammatory processes are taken up briefly. In addition to the roentgenographic manifestations of these conditions, emphasis is laid upon their clinical and pathological characteristics. In this same chapter are included Boeck's sarcoid, lymphogranulomatosis, and osteoid osteoma. It is interesting to observe the difference of opinion among European and American observers on the characteristics of some of these entities.

Those interested in developmental abnormalities, hereditary changes, and diseases of bone related to congenital variations from normal will find an unusual opportunity for study in Cocchi's Chapter K. It would be difficult to improve this explicit summation of a somewhat dry subject. The description of the innumerable variations, their differential diagnosis and clinical application are lightened and the reader's interest stimulated by numerous roentgenographic reproductions, sketches, photographs, and tables of heredity.

Included in this chapter are the bone changes associated with familial jaundice, sickle-cell and Cooley's anaemia, erythroblastosis foetalis, and the various forms of lipoid disease, as well as neurofibromatosis and related conditions.

The final chapter in *Volume 2* deals briefly with the benign and "semimalignant" tumors of bone, which include giant-cell tumors and chondroblastomata.

This book represents the result of an unusual effort to bring to the reader more than the mere essentials of the conditions under discussion. It is not written for the radiologist alone, but will give stimulation and pleasure to anyone interested in a comprehensive clinical, radiological, and pathological study of a given problem. The many excellent reproductions of roentgenograms, the numerous photographs, sketches, diagrams, and tables help to emphasize and clarify the text. There is also a large and excellent bibliography. Schinz and his collaborators are to be congratulated on having secured the assistance of such expert photographers and engravers. The reproductions are of admirable quality, such as is seldom found in textbooks.

That this book and the preceding volume are in fact to be translated into English is a matter of congratulation. It is hoped that the translation will be available in the near future, so that this excellent material may reach an even wider audience. It is a book which should not be missed by anyone interested in the conditions discussed; it is one to be constantly consulted; and even better it is one to own.

AN ATLAS OF HUMAN ANATOMY. Barry J. Anson, Ph.D. Philadelphia, W. B. Saunders Company, 1950. $11.50.

The *Atlas of Human Anatomy* is a beautiful example of medical publishing and illustration. Well bound and finely printed, it presents to the student and practitioner an atlas of gross anatomy as authoritative as it is attractive. The author, long Professor of Anatomy at Northwestern University School of Medicine, planned an anatomy "whose pictoral content would be based upon new dissections, serially prepared, and upon variable morphological features statistically presented". Accordingly, most of the 1,275 illustrations have been prepared from original dissections in Dr. Anson's laboratory by several well-known medical artists. The drawings are "neither warped to conform to preconceived, stereotyped concepts of human morphology, nor simplified to serve as transitory chartings for a laboratory excursion". Two very striking features of the illustrations may be mentioned,—the progressively deeper dissections and the unique method of indicating magnification by showing a representation of a magnifying glass held over the particular area magnified.

The atlas is divided into seven sections, each devoted to the anatomy of a major region of the human body,—the head, the neck, the upper extremities, the back and thorax, the abdomen, the pelvis and perineum, and the lower extremities. There is no body of text, but the detailed legends accompanying the illustrations constitute the equivalent of a laboratory manual.

This volume, the fruit of the experience of a fine teacher, represents the culmination of years of thoroughgoing investigative work. The author has fulfilled his purpose of preparing An Atlas of Human Anatomy which will be continuously useful to the doctor, since it is based "upon the artists' unbiased portrayal of dissection".

ANATOMIE CLINIQUE ET OPÉRATOIRE (Clinical and Operative Anatomy). J. Maisonnet et R. Coudane. Paris, G. Doin et Cie., 1950.

The title *Anatomie Clinique et Opératoire* could be translated as "surgical anatomy". This large work, however, is more than that. Many surgeons are probably familiar with some of the older French topographic anatomies, especially those of Testut and Jacob. These were excellent texts but now, in view of recent progress in the field, are not always adequate. It was the purpose of the authors of this anatomy to assemble all the anatomical and surgical information which would be useful both to the student and to the surgeon. Many years of teaching experience helped them to determine the elements essential to descriptive and regional anatomy, physiology, symptomatology, roentgenography, congenital and acquired deformities, and limited regional operative techniques, together with the most common approaches and methods of exploration.

The text is divided into three volumes; there are 2616 pages and 2657 illustrations. The various subjects are well balanced, but essentially this is an anatomical textbook. The division of the subject matter follows a somewhat conventional pattern. The first volume deals with the extremities and the exterior structures of the abdomen and pelvis. The second volume describes the abdominal cavity and its contents, and the thorax with the contents of the thoracic cavity. The third volume is devoted to the neck, spine, and head. Unfortunately there is no general index, although the third volume contains an alphabetical index of all the surgical operations discussed in the text.

The orthopaedic surgeon will be interested primarily in the first volume and parts of the third. Discussion of operative techniques is of necessity limited to the essential approaches, most useful procedures, amputations, and disarticulations; but the sections dealing with these are concise, clear, and very informative. The correlation of the clinical data with the anatomy and the roentgenographic findings is excellent. The numerous admirable illustrations, diagrams, cross sections in various planes, and line drawings, combined with the splendid organization of the descriptive material, make this a superior textbook. The illustrations should be of value even to those readers whose knowledge of French is limited. The authors have purposely

eliminated bibliographical references: they attempted to create a practical textbook, excluding the unessential and unproved. The large amount of new practical information is responsible for the size of the work.

The authors have succeeded in providing an eminently useful and practical textbook for the student and the advanced surgeon. It is regrettable that the difference between French and English technical terms may prevent this very good text from being used by as many surgeons and students as it rightfully deserves. An English translation of this book would doubtless find a large group of enthusiastic readers.

DIAGNOSTIC ROENTGENOLOGY (Renewal Pages). Ross Golden, M.D., Editor. New York, Thomas Nelson & Sons, 1950.

Thomas Nelson & Sons, ever anxious to keep their well-known loose-leaf series up to date, have released the fourth issue of renewal pages for *Diagnostic Roentgenology*. The 1950 Renewals consist of, first, important additions to the chapter on "The Roentgen-Ray Diagnosis of the Skull and Intracranial Contents" by the late Cornelius G. Dyke, M.D., which were prepared by Arthur E. Childe who cites recent advances in technique and references in the literature pertaining to them.

The second and more important addition is an entirely new chapter on "The Roentgenologic Diagnosis of Diseases of the Bones" by David G. Pugh of the Section on Roentgenology of the Mayo Clinic. Dr. Pugh, recognizing that not all aspects of diseases of bone can be touched upon in the space at his disposal, has been careful to select those aspects which are of the greatest importance and which are encountered most frequently. This new chapter replaces the former chapter "Diagnosis of Diseases of Bones" by Hodges, Phemister, and Brunschwig, to whom Dr. Pugh pays tribute for the stimulus and knowledge their work gave him in the preparation of his chapter.

Accompanying the renewal pages is a carefully revised index.

RECENT ADVANCES IN PHYSICAL MEDICINE. Edited by Francis Bach, M.A., D.M. (Oxford), D. Phys. Med. Philadelphia, The Blakiston Company, 1950. $4.50.

This book consists of seven sections containing thirty-two chapters and three appendices. Thirty-eight contributors from leading hospitals and medical centers in England have brought Physical Medicine up to date from the standpoint of basic sciences, research, education, and medical practice.

In the chapters on electrodiagnosis, clinical electromyography is clearly described and illustrated. The sections on "Organization of a Physical Medicine Department" and "Rehabilitation and Resettlement" present recent useful developments as integral parts of hospital practice.

This book contains useful information for physical therapists and hospital administrators as well as physicians. The references given are to both the European and American literature.

PROGRESSIVE RESISTANCE EXERCISE. TECHNIC AND MEDICAL APPLICATION. Thomas L. DeLorme, B.S., M.D., and Arthur L. Watkins, A.B., M.D. New York, Appleton-Century-Crofts, Inc., 1951. $5.00.

Readers of *The Journal* are already familiar with progressive-resistance exercises through the several articles published in its pages. In this small book the authors have tried to include in concise and practical form the principles of the treatment, indications for its use, specific instructions about the exercises to be used, and the results to be expected. In an introduction to the volume is told the story of the development of this type of exercise therapy at the Gardiner General Hospital in Chicago.

The Pope Foundation, Inc., and the National Foundation for Infantile Paralysis have provided for much of the study and research. The establishment of the Pope Memorial Exercise Clinic in the Department of Physical Medicine at the Massachusetts General Hospital has made possible the development of equipment and techniques to investigate the effectiveness of progressive-resistance exercises in a large number of clinical conditions.

The chapter on "Physiology" by Dr. Frances A. Hellebrandt is a valuable introductory chapter.

All interested in physical medicine, as well as those in other specialties, who appreciate the part which these exercises can play in the rehabilitation of patients recovering from diseases and injuries of the joints, will find this book of value.

THE 1950 YEAR BOOK OF ORTHOPEDICS AND TRAUMATIC SURGERY (November, 1949–November, 1950). Edited by Edward L. Compere, M.D., F.A.C.S. Chicago, The Year Book Publishers, Inc., 1950. $5.00.

In this issue of The Year Book, Dr. Compere has included an introductory chapter on progress in orthopaedic surgery in the past ten years; he enumerates some of the more striking changes in treatment which have taken place in this period, also the acceptance of theories of etiology of disease which differ markedly from those held in an earlier period.

The book measures up to others in this series and, in a compact form, covers the most important articles

in this field of surgery which have appeared during the past year, both in the American and in the European literature. The Year Book must be of great value to those who do not find it possible to read the original articles bearing on these subjects as they are published, but who do wish to keep in touch with the developments in this specialty.

COAGULATION, THROMBOSIS, AND DICUMAROL. WITH AN APPENDIX ON RELATED LABORATORY PROCEDURES. Shepard Shapiro, M.D., and Murray Weiner, B.S., M.S., M.D. New York, Brooklyn Medical Press, 1949. $5.50.

This excellent monograph should be read by anyone interested in the therapeutic uses of dicumarol. The available knowledge and the current theories of the clotting process are clearly developed and well expounded. The chapter on this subject and the two that follow provide excellent reading for anyone beyond the first year in medical school.

The rationale and the technique of dicumarol administration are presented in great detail. Much of this information will be not only new, but of great importance to the majority of those who now prescribe the drug. Many of the untoward results presently encountered, attributable to both inadequate and overenthusiastic dosage, will be avoided if the plan of dosage proposed by the authors is followed.

Being a surgeon, the reviewer feels that the discussion of the place of surgery in the prevention of pulmonary emboli was handled a little casually, but otherwise only approbation can be offered.

The appendix on technique is excellent and the methods described should be easy to follow. There is an excellent bibliography.

THE HINGE GRAFT OR GINGLYMUS IMPLANT. Arnold K. Henry, M.B., M.Ch. (Hon.), F.R.C.S.I. Edinburgh, E. and S. Livingstone, 15 Shillings; Baltimore, The Williams and Wilkins Company, 1950. $3.00.

This sixty-four page monograph by Mr. Arnold K. Henry, Emeritus Professor of Clinical Surgery in the University of Egypt and now Professor of Anatomy in the Royal College of Surgeons, Ireland, is concerned with several specialized applications of the osteoperiosteal graft. The "hinge graft" is made by fracturing the osteoperiosteal graft obliquely in several places with a chisel. The flexible periosteum then permits bending the graft in only one direction.

The author has found that these "hinge grafts" can be put across joints to improve stability of the bone in a variety of deformities of the joints of the lower extremities and has used the method in the reconstruction of fingers and of prehensile forearm stumps by attaching tendons to the bone.

Throughout the book are brief, amusing asides which reveal something of the character of the author.

A TEXTBOOK OF NEUROPATHOLOGY. WITH CLINICAL, ANATOMICAL AND TECHNICAL SUPPLEMENTS. Ben W. Lichtenstein, B.S., M.S., M.D. Philadelphia, W. B. Saunders Company, 1949. $9.50.

This textbook is written from the viewpoint of a clinical neurologist, and the presentation of the work is anatomical. The first three chapters deal with the scope and methods of neuropathology, and provide a general listing of those agents and factors which may cause neurological disease. Succeeding chapters contain descriptions of the various types of degenerative and destructive changes which occur in the nervous system, the regenerative processes, and inflammatory diseases, hemorrhage and vascular disorders, hyperplasia, neoplasms, malformations and deformities, adventitious metabolic substances, and muscle disorders. A clinical supplement lists a large number of neurological syndromes and diseases, with brief descriptions of the important features of each. This offers a convenient summary, relating the anatomical aspects with the clinical concepts, and should be particularly useful to pathologists.

Writing a textbook of pathology from the anatomical viewpoint only makes difficult the task of explaining the fundamental disease processes—that is, *pathology*—in dynamic terms. The result must necessarily be limited to descriptive morbid anatomy with virtually no consideration of pathological physiology and biochemistry. The author is well aware of this problem.

From the standpoint of the pathologist, it might have been desirable to have placed greater emphasis on the *general pathology* of nerve tissues,—that is, how the various components react to injuries in general and the sequences which are involved. From the clinician's point of view, the book represents a scholarly attempt to bridge the gap between morphological changes in tissues and the clinical diseases with which they may be associated.

A MANUAL OF CEREBRAL PALSY EQUIPMENT. Sponsored by Zeta Tau Alpha; prepared and published by the National Society for Crippled Children and Adults, Inc. Chicago, 1950. $3.75.

This excellent manual describes some 127 items of equipment and aids for the care, treatment, and training of the victims of cerebral palsy. The description of each item is accompanied by a photograph showing

it in actual use. In addition, there are working diagrams for the construction of the piece, together with material specifications and directions.

The manual has been prepared for, and its distribution is limited to, physicians and professional personnel working closely with those afflicted with cerebral palsy. For their convenience the manual contains not only the usual indexes and bibliography, but also a list of commercial firms which manufacture and distribute equipment found useful in the treatment of cerebral palsy.

CLINICAL USES OF INTRAVENOUS PROCAINE. David J. Graubard, M.D., and Milton C. Peterson, M.D. Springfield, Illinois, Charles C. Thomas, 1950. $2.25.

It is the purpose of the authors of this small but attractive volume to compile all the published data on the subject of intravenous procaine and its therapeutic uses into one readily available source. Thus, a summary of what is known of the subject can easily be read in about thirty minutes.

The text is divided into ten chapters dealing with such subjects as chemistry and pharmacology, intravenous local anaesthesia, pruritus, serum sickness, analgesia in burns, acute arrhythmia during anaesthesia, acute anterior poliomyelitis, pain in traumatic and inflammatory conditions, and other indications for the use of intravenous procaine. To each chapter is appended a large bibliography.

ACKNOWLEDGEMENTS

The Journal wishes to acknowledge receipt of the following publications, which have been sent to the Editorial Department:

Acta Chirurgiae Orthopaedicae et Traumatologiae Cechoslovaca (Prague), **17:** Nums. 1, 8, 1950.
Acta Chirurgica Belgica (Bruxelles), **49:** Nos. 6–9, 1950; **50:** No. 1, 1951.
Archiva Medica Belgica (Bruxelles), **5:** Fasc. 4–6, 1950.
Archivos del Hospital Universitario (Habana), **2:** Núms. 4, 6, 1950.
Arquivos de Clinica (Rio de Janeiro), **11:** No. 2, 1950.
Boletin del Hospital Militar (Habana), **3:** Núms. 1–3, 1950.
Boletin del Instituto de Clinica Quirurgica (Buenos Aires), **26:** No. 188, 1950.
Boletin del Instituto de Patologia Medica (Madrid), **5:** Núms. 6–12, 1950; **6:** Núm. 1, 1951.
Bolitines de la Sociedad de Cirugia de Rosario (Argentina), **17:** Nos. 2–6, 1950.
Cleveland Clinic Quarterly (Ohio), **17:** No. 4, 1950; **18:** Nos. 1–2, 1951.
The Crippled Child (Chicago, Illinois), **27:** No. 5, 1950; **28:** No. 1, 1950; **30:** Nos. 4–5, 1950.
Gazeta Medica Portuguesa (Lisboa), **3:** No. 4, 1950.
Georgia Warm Springs Foundation Annual Report, Warm Springs, Georgia, 1950.
Harper Hospital Bulletin (Detroit, Michigan), **8:** Nos. 4, 6, 1950; **9:** No. 1, 1951.
Hospital for Joint Diseases (New York, N. Y.), Bulletin, **11:** No. 1, 1950.
International Health Bulletin of the League of Red Cross Societies (Geneva, Switzerland), **2:** No. 4, 1950.
The Journal of the National Association of Chiropodists (Boston, Massachusetts), **40:** No. 8, 1950.
The Journal of the Royal Egyptian Medical Association (Cairo), **33:** Nos. 6–12, 1950; **34:** No. 1, 1951.
The Medical Journal of Malaya (Singapore), **5:** No. 1, 1950.
Medical Journal of Osaka University (Japan), **2:** No. 1, 1950.
Medica (Matanzas, Cuba), **9:** Núms. 5–6, 1950.
Medicina Practica (Zaragoza, Spain), **8:** Núms. 71–73, 1950.
Mississippi Valley Medical Journal (Quincy, Illinois), **72:** No. 6, 1950.
Medical Radiography and Photography (Rochester, New York), **26:** Nos. 3–4, 1950.
National Multiple Sclerosis Society (New York, N. Y.), "Multiple Sclerosis and Its Treatment", by George A. Schumaker, M.D.
Polski Przeglad Chirurgiczny (Warszawa, Poland), **22:** Nrs. 4–6, 1950.
Revista do Hospital das Clinicas (Sao Paulo, Brazil), **5:** Núm. 2, 1950.
Revista Medica da Aeronautica (Rio de Janeiro), **2:** Núms. 3–4, 1950.
Revista Medica de Arequipa (Peru), **1:** Nos. 2–3, 1950.
Revista Medica Municipal (Rio de Janeiro), **15:** Núm. 2, 1949.
Sanidad y Beneficencia Municipal (Habana, Cuba), **9:** Núm. 4, 1949.
Sociedad Argentina de Ortopedia y Traumatologia (Buenos Aires), **15:** Nos. 5, 7–8, 1950.
Sociedad de Cirugia de Cordoba (Argentina), Boletines y Trabajos, **10:** Nros. 6–8, 1949; **11:** Nros. 1–6, 1950.
Sociedad Nacional de Cirugia (Habana, Cuba), Trabajos y Memorias, **5:** No. 1, 1951.
Tenth Anniversary Celebration of the Alfred I. du Pont Institute of The Nemours Foundation (Wilmington, Delaware), 1950.
United States Armed Forces Medical Journal (Washington, D. C.), **1:** Nos. 10–12, 1950; **2:** Nos. 1–3, 1951.